JUL 27 1928

THE AUGUST SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

RECENT BOOKS OF SCIENTIFIC INTEREST

Snapshots of Science. EDWIN E. SLOSSON, xvi, 299 pp., illustrated. $2.00. New York, 1928.

Recent applications of science to industry and agriculture; contributions of chemistry to medicine; novel inventions and how they affect daily life, and many other reprints of fascinating articles by Dr. Slosson which have appeared during the last three years.

An Outline of Physics. ALBERT EDWARD CASWELL. xiv, 773 pp. $4.25. New York, 1928.

After many years of study and experiment, the author has adopted for this book a new mode of presentation which seems to make the subject matter of physics more vital and more stimulating.

The Psychology of Abnormal People with educational applications. JOHN J. B. MORGAN. vii, 627 pp. $3.75. New York, 1928.

The purpose of Professor Morgan's book is to aid the reader to an understanding of the more common weaknesses in human nature to the end that character and personality deformities may be avoided.

The Frog: A Laboratory Guide. WALDO SHUMWAY. viii, 67 pp. $.90. New York, 1928.

A clear manual of dissection for this important laboratory form. The terminology follows that in Holmes: Biology of the Frog, revised edition, 1927. Following the anatomy of the adult frog come sections on histology and embryology.

Archimedes or the future of Physics. L. L. WHYTE. 83 pp. $1.00. New York, 1928.

In this new volume in the "To-day and To-morrow Series" the author points out how Physics, Biology and Psychology are now all converging upon the problem of life itself and how Physics has reached the borderland of metaphysics.

Wild Animal Pets. WILLIAM LOVELL FINLEY and IRENE FINLEY. 311 pp., illustrated. $3.00. New York, 1928.

The author, as state biologist and game-warden, has lived daily with the life of the wild, and his opportunities for observation have been unexcelled. These charming sketches are the fruit of all his long observation and experience.

Die Geschichte des Atlantischen Ozeans. HERMANN VON IHERING. vii, 237 pp. 9 maps. $4.25. Jena, 1927.

The book attempts to gather and critically analyze all material available regarding the history of the Atlantic Ocean. Chapter eleven treats on the history of the flora of Patagonia and throws some interesting side lights on Wegener's theory.

Foibles of Insects and Men. WILLIAM MORTON WHEELER. xxvi, 217, xi pp. $6.00. New York, 1928.

The author tells about the peculiarities not only of the wasps, ants and other insects, but also of the entomologists who study them. Most of the chapters have appeared in various scientific journals. The paper on Leptothorax emersoni has been rewritten and expanded.

Theoretical and Experimental Physical Chemistry. J. C. CROCKER and FRANK MATTHEWS. viii, 581 pp. $6.00. New York, 1928.

A comprehensive treatment, stressing concrete experimental foundations of the subject rather than abstract theory. The book is unusually accurate and up-to-date in its discussion of recent developments in the field of physical chemistry.

Handbuch der anorganischen Chemie in vier **Baenden.** HERAUSGEGEBEN VON R. ABEGG. Volume IV, 3, I. xii, 522 pp. 50 figures. 222 tables. $12.00. Leipzig, 1928.

This new volume of "Abegg" contains "Die Edelgase" by Dr. E. Rabinowitsch. It is the first section of the eighth group of the periodic system. The next section: Iron, will follow soon and the publishers hope to complete the work within a comparatively short time.

Bryan, the Great Commoner. J. S. LONG. 422 pp., illustrated. New York, 1928.

The author sees the Great Commoner as an amazing dramatic figure that grew out of the strange welter of events of the last thirty years—a cross between Saint George and Don Quixote.

Reclam, Praktisches Wissen. Herausgegeben unter Mitarbeit erster Fachgelehrter. xxi, 816 pp. 948 illustrations, 42 plates. $5.00. Leipzig, 1928.

This large volume is a popular encyclopedia of present-day knowledge. It is divided into fifteen chapters, beginning with astronomy and the theory of relativity and ending with a chapter on how to build one's own home.

Culture and Social Progress. JOSEPH KIRK FOLSOM. ix, 558 pp. $3.00. New York, 1928.

This volume is an outgrowth of the author's belief that there is a growing demand among students and other young readers for a straightforward statement of the new morality which is slowly taking shape in the minds of thinking people.

Psychology for Executives. A study of human nature in industry. ELLIOTT DUNLAP SMITH. xiii, 262 pp. $3.50. New York, 1928.

The book aims to supply executives with a clear understanding of human nature. It is written in plain and simple terms and contains helpful and illustrative cases drawn from the author's experience.

The books noted above may be obtained at the publisher's regular rates from
THE SCIENCE PRESS DISTRIBUTING COMPANY, Grand Central Terminal, N. Y. (See page x.)

THE SCIENTIFIC MONTHLY

AUGUST, 1928

THE WASTING HERITAGE OF THE NATION

By HUGH HAMMOND BENNETT

BUREAU OF CHEMISTRY AND SOILS, U. S. DEPARTMENT OF AGRICULTURE

I

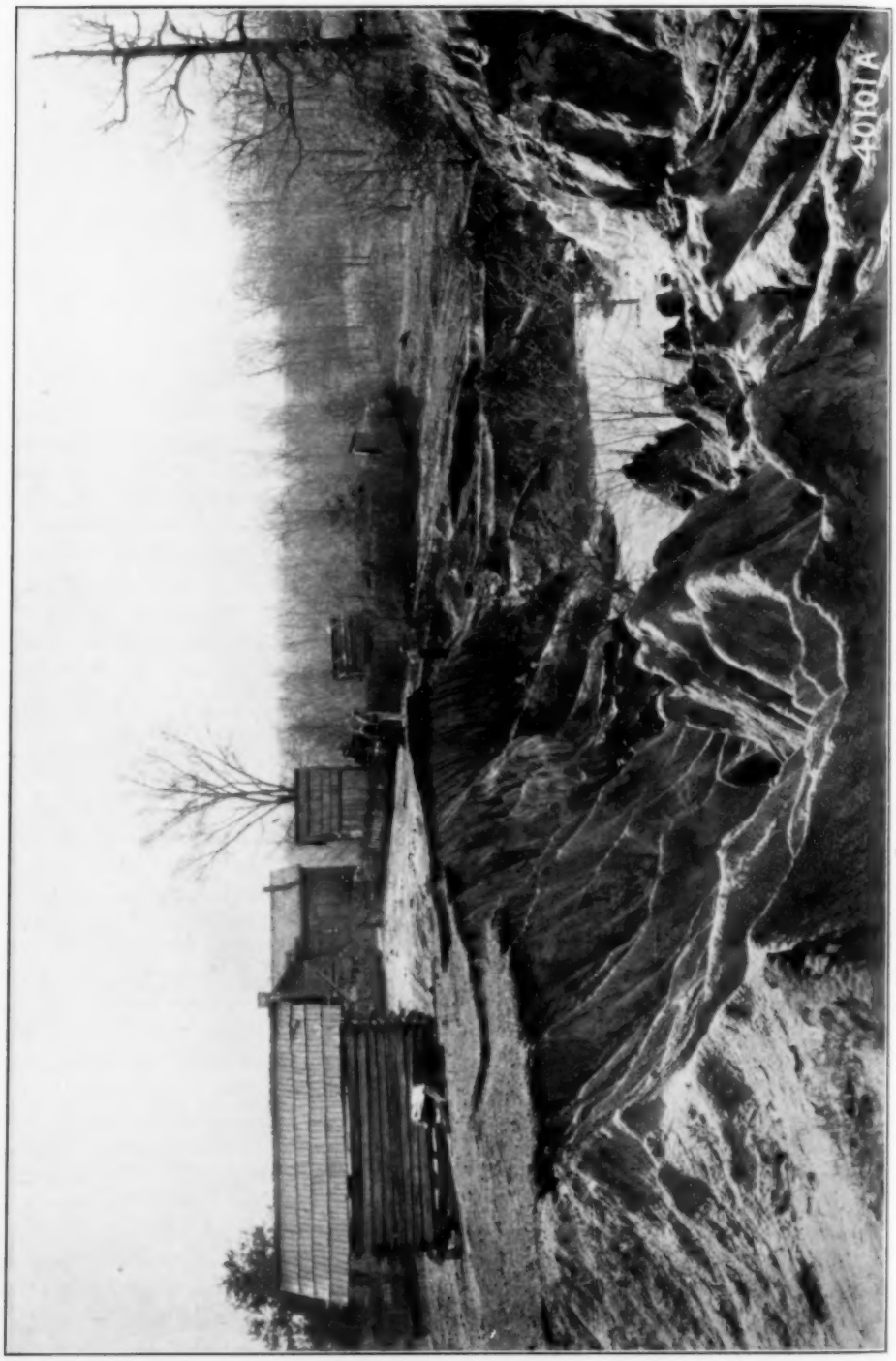
Soil wastage by erosion is the most serious problem relating to land utilization in this country. It is the direct cause of the distressing financial condition of thousands of farmers struggling with lands enfeebled or worn out by rain-wash. Crop surpluses, with their depressing effect upon prices of farm products, come and go; but land impairment by erosion is a costly evil that stays. Indeed, it is a problem which with the prevailing absence of national concern about it, is growing steadily worse. It affects nearly all sloping areas over most of the uplands of the nation, and there is but little upland which is without slope. Even the areas that seem flat to the eye usually have sufficient slope for rain-water to flow off the fields and pastures. Wherever this happens there is some washing away of the soil. The removal is slower on the smoother lands, and the effect is less serious on some lands having peculiar resistance to the process. With increasing slope the transporting and eroding capacity of running water is greatly enlarged, since the load flowing water is capable of carrying, and also the abrasive effect, increases enormously with the velocity.

We sometimes hear farmers and even scientific agriculturists say, "Erosion is not a problem in our locality." In some places it is not a very serious problem, to be sure; but in many other localities where it is believed not to be operative at all, much damage is actually being done. In time the cumulative effect of soilwash becomes painfully apparent, as spots of unproductive clay and exposed bedrock and as fields from whose surface the entire soil has been stripped off. The hideous gullies that mar the landscape of so many localities represent the more advanced and spectacular work of erosion; and, although something in excess of thirteen million acres of formerly cultivated land in this country have been permanently ruined for farming purposes by gullying, this form of devastation constitutes but a small fraction of the wastage.

It is sheet erosion that is doing most damage to our farm lands and over-grazed pastures. By this process the surface of the ground is gradually planed down more or less equally at all points. Every heavy rain and even the showers of springtime strip from the cultivated land sheets of soil matter, and this from the surface, the richest part of the fields. If, after a fall of rain, one looks, one sees wherever there is cultivated and over-grazed land water flowing across the slopes and down the rills and brooks, not clear but discolored or turbid with soil material gathered from the countryside. This coloring matter represents so much soil and soil fertility gone for eternity, so far as the areas whence came the material are concerned.

II

Abnormal soil washing, with the helpful assistance of man, is doing more dam-



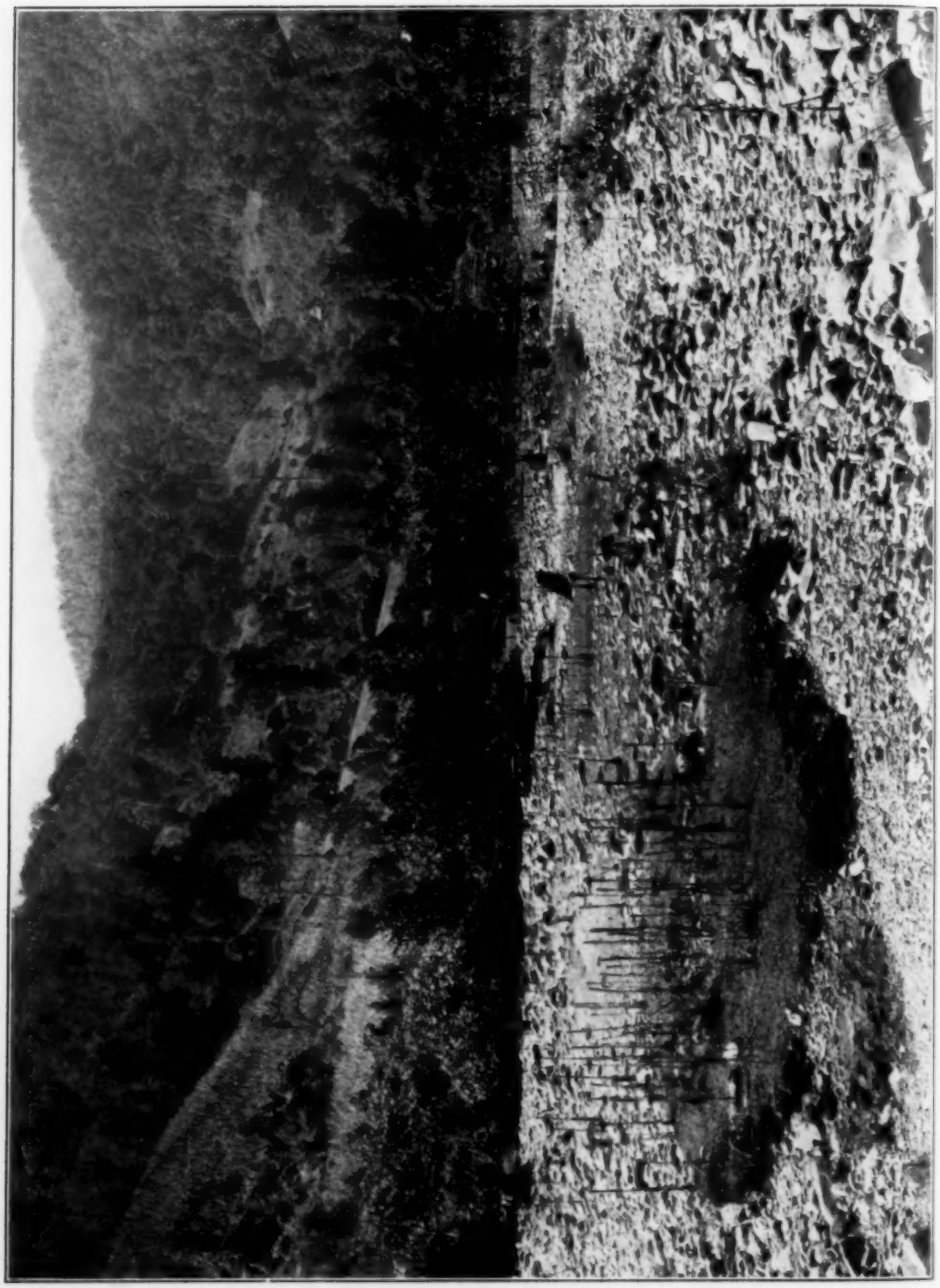
GULLY NEAR FARM HOUSE, PANOLA COUNTY, MISSISSIPPI

LAND DESTROYED FOR CROP USE BY UNRESTRAINED EROSION
NEAR CONTACT OF THE PIEDMONT AND BLUE RIDGE MOUNTAINS.

age to the agricultural lands of the nation than all other processes, both natural and artificial, combined. The writer is conscious of the fact that this statement covers considerable territory, being fully cognizant of the large amounts of plant food lost from the soil by the leaching of rain-water and by the crops removed, and that in past time volcanoes have poured over the earth sheets of molten lava; that earthquakes have caused mountainsides to crack and go down into valleys as vast, destructive landslides; that coal strippers and gold diggers have churned up many acres in search for hidden wealth; and that many other activities of man have despoiled the ground surface. Nevertheless, the damage done by rainwash greatly exceeds the combined effects of all these other activities of both man and nature. More than eight tenths of the area of the United States is underlain by sedimentary deposits; that is, rocks and unconsolidated strata composed of material that was washed, largely or entirely, from older land areas, some of which have been completely effaced from the earth. These water-formed beds are thousands of feet in thickness. It is not uncommon to drill into them more than four thousand feet for oil. Through the eons of geological periods the rocks of ages have decayed to give the material of our soils, and from the very beginning rainwater impinging against these detrital products have torn them asunder and distributed them to the seas to form new land areas of coastal marsh and submerged continental shelfs. The gashes this instrument has cut are utterly beyond calculation. Some parts of the Blue Ridge Mountains of the Appalachian System have been hewn down through thirty thousand feet of decayed rock and eroded soil, or ten times their present height.

Long before the ancients began to build temples to the sun, Mother Nature was busy fashioning such superb examples of rock architecture as the Grand Canyon of the Colorado, Victoria Falls and the Magotes of Western Cuba. Man can not hope to match these structures of destruction. Nor should there be any desire to match them, for they are the products of tearing-down processes. Erosional work of this kind represents the accumulated effect of slow geologic processes that always have been active

GULLY NEAR FARM HOUSE, PANOLA COUNTY, MISSISSIPPI



THE WORK OF A NORTH CAROLINA FLOOD

IN THE BLUE RIDGE REGION, WHERE THE RAINFALL WAS HEAVIEST

and always will be, inexorably abrading rock and soil in striving to level down the earth's surface.

Nevertheless, man has entered very actively upon the task of assisting nature with the work of land destruction. By cultivating unprotected and excessively steep slopes, hundreds of thousands of square miles have been brought to complete ruin throughout the world, and far greater areas have been seriously impaired by unrestrained rainwash. Solid rock and sterile, gullied slopes frown down from stripped uplands over vast areas of China and Asia Minor. Unwise treatment of sloping land by the farmers of the past has so restricted the area of China's arable land that hordes of highlanders have been driven into the valleys for sustenance, or forced to husband their remaining soil upon terraces built like scaffolds along the sides of hills and mountains. With the best possible utilization of the remaining soil, famines are continually recurring upon that disturbed part of the earth's surface. In some parts of the world wastage of fertility by erosion has caused the downfall of nations, and even the destruction of civilizations.

III

Youthful America is not guiltless of unwise use of the land upon a large scale. Steep slopes and land that washes much too readily have been used for crops without provision for checking rainwash; indeed, they often have been used in such manner as to encourage and accentuate the wastage. Even grazing lands have been sorely impoverished or destroyed in many parts of the west and in some parts of the east. The impoverishment and devastation, most of which could have been prevented, have gone on in nearly all parts of the country, from the Gulf to the Canadian border states, from New Jersey to California. At the present moment the rate of land depreciation from this cause is greater than ever, and, unless very largely increased efforts are made to check the inroads, it can safely be asserted that we are but upon the threshold of this process of land despoliation.

HIGH PIEDMONT PLATEAU

WHERE THE SOIL IS ERODING SO RAPIDLY TREES ARE HAVING DIFFICULTY ESTABLISHING THEMSELVES. THE LAND WAS FORMERLY CULTIVATED.

If we continue to twiddle thumbs and warn our brothers not to be stampeded by the wailing of those apostles and prophets, who, brimming with enthusiasm or pessimism, recurrently wave red flags of fear and point to direful dangers lurking around the corner, then we of to-day are going to be the recipients of much tongue-lashing by our children a few generations hence. Already such blasphemy is to be heard in many parts of the country. Down in the southern Piedmont, for example, where ninety thousand acres of formerly good farm land have been destroyed in a single county, serious-minded citizens speak vehemently of the shameful land practices of the farmers of one, two or three generations ago, not to mention some of those who, still operating, call themselves farmers instead of soil miners. The ninety thousand acres that stare them in the face, a grinning skeleton of land that could have been saved, is not a guess. The area was studied in detail by experienced soil scientists and its outlines carefully plotted on a government map. It was classed as gullied land having no further agricultural value, save for an occasional strip temporarily left between expanding gullies. Bedrock has been exposed in a thousand places. In brief, this area has been so completely devastated over most of its extent, it can not be reclaimed to cultivation until centuries of rock decay have restored the soil, and it has only moderate value for tree growth.

IV

Too few are concerned about land destruction of this nature, even when it is pointed out that this wasted Piedmont area is but one of a vast number of similarly eroded areas throughout the country, many equally bad and others worse. If a foreign nation should invade this country and destroy ninety thousand acres of land, who doubts the nation would hasten to spend twenty billion dollars to redress the wrong or as many billions as might be necessary. That rainwater was the agency of destruction, too many people look upon the situation with indifferent complacency, regarding it as regrettable, perhaps, but as an unavoidable natural eventuality.

It can be avoided. Not with this par-

SHOWING EROSIONAL DEBRIS

CAUGHT BY A LOG OBSTRUCTION IN A STREAM OF WESTERN NORTH CAROLINA.

CULTIVATION ON THE BLUE RIDGE

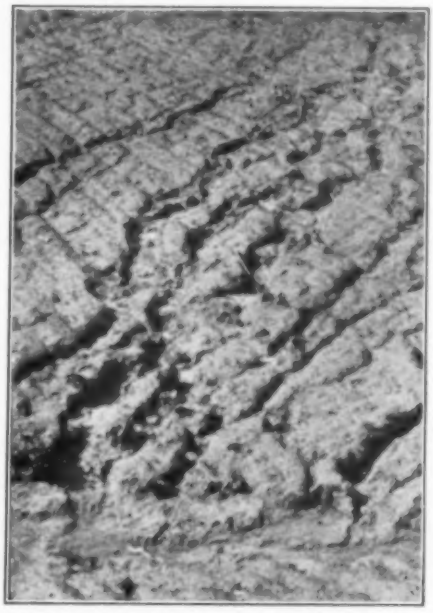
IT WAS A CRIMINAL ACT TO ATTEMPT CULTIVATION ON THIS STEEP BLUE RIDGE SLOPE, EVEN IF THERE IS NO MAN-MADE LAW AGAINST THE FOLLY.

ticular tract; no, that is permanently lost. But this kind of wastage can be largely prevented, if we will. Other areas, not yet destroyed, can be saved by terracing and other means. This has been proved abundantly through the southeastern states, where thousands of energetic farmers have kept their sloping fields in good state of productivity for more than two generations by the practice of hillside terracing, a system of contour embankments.

In another county, of the coastal plain region, seventy thousand acres of former rich soil have been gullied beyond repair. In one place where a schoolhouse stood forty years ago, gullies more than a hundred feet deep now finger through hundreds of acres of land, all formerly good soil, whose reclamation would baffle human ingenuity.

VIEWING THE REMNANTS OF A WASTED FARMSTEAD IN THE PIEDMONT

In the great region of loessial soils, the Brown Loam Belt that follows along the east side of the Mississippi River from Baton Rouge, Louisiana, northward across Mississippi, Tennessee and south-



FINE GRAIN SOIL IN NORTHEAST KANSAS

IN THE FALL OF 1927 A SINGLE RAINY PERIOD TOOK OFF MORE THAN FORTY TONS OF SOIL PER ACRE FROM THIS LAND. THE YOUNG GRAIN ALSO WAS LARGELY WASHED OUT.

western Kentucky, and onward far up the Missouri and its tributaries, county after county includes ten, twenty or thirty thousand acres which have been destroyed by gullying and sheet erosion. In some of the more southerly counties of this region agriculture has been largely driven out of the uplands, and many tracts of rich alluvial soil have been buried beneath a blanket of comparatively inert sand deposited by flood

CHANNEL–TRENCH EROSION

ABOUT TO DESTROY A GOOD GRAZING VALLEY IN THE ARID SOUTHWEST.

water. Stream channels have been choked with erosion-débris, and overflows have become so exceedingly common that large tracts of highly productive alluvium, formerly tilled, are now rated as swamp land having little value for any purpose. Some streams, formerly navigable, have been so choked with sand and mud they can no longer be plied by boats.

FIELD NEAR RALEIGH, N. C.

THIS EXCELLENT FIELD, FORMERLY BADLY WASHED AND UNPRODUCTIVE, HAS BEEN RECLAIMED BY TERRACING.

SHEET EROSION

RICH TOPSOIL REMOVED FROM ONE PART OF THE FIELD TO SMOTHER THE CROPS IN ANOTHER PART. THIS FIELD IS ON FERTILE IOWA BLACK LAND.

Dr. E. N. Lowe, state geologist of Mississippi, has this to say of the situation:

In many of our northern uplands, washing of the soil is progressing so rapidly, without let or hindrance over large areas, that some necessary measures must be adopted soon to arrest the process, otherwise vast areas of formerly agricultural lands will become hopeless wastes. Large areas in at least a dozen upland counties of north-central Mississippi have already reached such a condition of soil depletion that they are now hardly suitable for any kind of agriculture, and their taxable values are reduced accordingly. . . .

The erosion of these uplands has resulted not only in enormous losses of valuable agricultural soils, but also in concomitant stream-filling throughout these areas. Volumes of silt and sand after every heavy shower are poured into the streams from every furrow, gully and rill that trenches the hillsides, resulting in filling of their channels. The obliteration of their channels causes overflow of the streams after any considerable rain, with deposition of sand over valuable bottom lands, often doing irreparable damage. . . .

For years rapid and destructive filling has affected the Coldwater. Forty years ago boats of large size came up the river to Coldwater to load cotton. Now no kind of boat can come up Coldwater River, so choked is it with sandbars. Thirty years ago a large fertile cotton plantation existed on the river flat just below Coldwater; for years past it has been abandoned, and is grown up in willow thickets, as useless land, all because the filling of the river channel has caused constant overflows on this land, covering it with sand beds.

CROPS SMOTHERED BY TOPSOIL

WASHED FROM ADJACENT SLOPES. SHEET EROSION IN IOWA, WHERE NOTHING IS BEING DONE TO CONTROL THE WASTE.

EROSION IN THE TRANS-PECOS COUNTRY OF TEXAS

THIS STARTED IN A PLACE WHERE CATTLE REMOVED ALL THE GRASS.

In the black belt of Central Texas, one of the greatest cotton-producing regions of the world, white areas representing the basal chalk and marl beds dot the landscape of the rolling sections. These are the product of erosion. They consist of non-arable land that has taken the place of some of the most productive cotton soil known anywhere. In one county 13.5 per cent. of the entire land area was classed as eroded land whose productive value has been very seriously impaired or practically destroyed.

V

Let's not get the notion that the washing away of valuable farm land is restricted to the southern states.

The government soil experts who recently completed a land survey of a

PROTECTING THE BOTTOM LANDS IN KANSAS

THE MAN IN THE BACKGROUND IS STANDING ON A TERRACE 8 FEET ABOVE THE MAN IN THE FOREGROUND, WHO STANDS ON MISSOURI RIVER BOTTOM LAND. THE LATTER IS EXTREMELY PRODUCTIVE SOIL OF THE WABASH SILTY CLAY LOAM VARIETY. THE TERRACE IS THE RESULT OF A DYKE BUILT ABOUT 10 YEARS AGO TO INTERCEPT THE EROSIONAL DÉBRIS SWEEPING DOWN FROM THE NEAR-BY UPLANDS. THE FARMER OBJECTED TO HIS RICH BLACK BOTTOMS BEING COVERED BY LESS PRODUCTIVE WASH FROM THE HILLS. THIS FILLING-IN TOOK PLACE OVER 40 ACRES AT THE RATE OF 1,200 TONS PER ACRE PER YEAR. IT ILLUSTRATES HOW VERY RAPIDLY SOIL MATERIAL IS BEING REMOVED BY RAINWASH, AND, ALSO, THAT NOT ALL OF IT PROCEEDS IMMEDIATELY TO TIDE-WATER.

(PHOTOGRAPH TAKEN ON OCTOBER 17, 1927, NORTHERN DONIPHAN COUNTY, KANSAS.)

REPRODUCTION OF BLACK LOCUST
IN THE VALLEY OF VIRGINIA: A GOOD CROP FOR WASHING HILLSIDES.

county in northeastern Kansas found that an average of at least six inches of soil had been removed from the uplands of the county, where the predominant soils are silt loams, highly productive types, as valuable for the growing of corn and wheat probably as any upland known to man.

Nearly all tilled slopes of this county were found to have suffered, some much more severely than others. In one part of this area that was examined by the writer in the fall of 1927, a tract of original timber was seen, which had from one to two feet of extraordinary rich silt loam soil overlying clay. This was so abundantly supplied with dark humus and so mellow and permeable it was easy to dig down with the bare hand to the depth of the subsoil. Outside the timber on the same degree of slope the same soil in most places had lost all the surface material down to the clay, and in many places six inches or more of the subsoil itself had washed away. Indeed, patches were found where both soil and subsoil had departed, leaving bedrock exposed. One valley was found by actual survey to have lost from eight to forty inches of soil over 86 per cent. of its upland area since clearing forty years ago. In apple orchards on these wasted lands the trees were making no growth, or were dying, as the result of excessive loss of moisture on the sun-baked clay in times of drought.

Near the Kansas-Nebraska line an apple orchard was seen in the bottom of a beautiful valley where the trunks of the trees had been completely buried by silt washed down from the adjacent hillsides and ridge crests. The raised surface of the ground stood among the branches of the trees, five feet above the original level of the orchard. The owner said the trees had shown no evidence of damage by the deposition. "But the trees were doing nicely before this washed-in material was deposited about them; they needed no more soil. The soil is needed very badly up there on the thin slopes where it came from."

PIEDMONT GULLY IN ANSON COUNTY, N. C.

ALMOST FILLED BY EROSION-ARRESTING PINES (ON FARM OF DR. J. H. BENNETT, WEST OF WADESBORO). THIS IS AN EXAMPLE OF WHAT SHOULD BE DONE ON MANY THOUSANDS OF ACRES OF LAND IN THE SOUTHERN STATES.

Close by this orchard a gully is advancing at a minimum rate of one hundred and fifty feet a year. This is seventy-five feet deep, three hundred feet wide in places and nearly three-fourths of a mile long. It is destined to destroy all the farm land in this fertile valley, and its diverging trenches undoubtedly will cut to pieces the adjacent highlands.

Many valleys in the youthful agricultural country along the Missouri and its tributaries have undergone the same or similar vicissitudes. As a result, fields, and in some instances entire farms, are being abandoned. Sheet erosion is gradually thinning down the gentler slopes far back from the river. In many places twelve or fifteen miles from the Missouri, numerous wheat and alfalfa fields seeded in the fall of 1927 were severely damaged during a single period of autumn rains. Each depression made by the seed drills was converted into a rillway or small gully, while the wheel tracks of the seeder rapidly grew into ugly ditches. Most of the young plants were washed out of the ground and forty tons of soil an acre were carried off the steeper slopes. The only instance observed in several Missouri and Kansas counties of this region where a farmer had done anything to check the wastage was that of a series of wheat-straw stacks placed in a depression at the base of converging slopes. One of these stacks had caught and held four hundred and thirty tons of soil which had been washed down from the near-by slopes during the rainy period referred to. That sort of thing, however, can scarcely be considered as a real effort at soil conservation; for the place to hold the soil is in the fields and not in the valleys after it has left the fields.

There are no soil-saving terraces in this region, as a rule. The farmers generally do not even know what they are. Practically nothing is being done to con-

VIRGIN TIMBER IN NORTHEAST KANSAS

THE SOIL HERE IS TWELVE TO TWENTY-FOUR INCHES DEEP OVER CLAY—MELLOW, RICH IN HUMUS AND OF SILT LOAM TEXTURE. OUTSIDE IN THE WEED PATCHES ALL THE TOP-SOIL HAS BEEN WASHED OFF DOWN TO THE CLAY, AND THIS ON THE SAME SOIL AND SLOPE AS THAT COVERED BY THE FOREST.

THE EFFECT OF GULLYING

FORMER SPLENDID VALLEY GRAZING LAND OF FAR-WEST TEXAS BEING DESTROYED BY GULLYING THAT HAD ITS BEGINNING IN A ROADWAY.

serve the soil; whereas a very great deal is being done to hasten its loss, such as plowing corn rows up-and-down the slopes, thus forming gutter-like "middles" to serve as ditches for concentration and increased scouring effect of rainwater. Where the rows accidentally follow the contour it is a common practice in springtime to plow furrows down the slopes in order to lead the water out

AN EXAMPLE OF COAST EROSION

TWO WEEKS OF SOUTHWEST WINDS CUT BACK THE SHORE-LINE TWENTY FEET ALONG THIS PART OF THE GULF COAST, AND IN DOING SO, DESTROYED CONSIDERABLE FINE TIMBER.

ARID SOUTHWEST HILLS

WHICH ONCE AFFORDED GOOD GRAZING FOR GOATS. OVER-GRAZING AND EROSION HAVE COMPLETELY DENUDED THEM OF VEGETATION. OVER LARGE AREAS NOT A TREE, NOT A BUSH, NOT ONE SPRIG OF GRASS IS TO BE SEEN. THE LAND IS SIMPLY A SKELETON OF FORMER CONDITIONS. IT IS A DESTROYED PART OF THE EARTH, AS GHASTLY AND USELESS AS A SUN-BAKED SKELETON.

of the inter-row depressions. Almost invariably these furrows grow into deep gullies that divide, capture and render useless for cultivation field after field.

This neglect of the land to the unceasing impoverishing effects of erosion is the rule, not the exception, throughout the entire central and upper Mississippi Basin. It is not restricted to the Missouri River area by any means.

VI

One might reasonably suppose that erosion is of negligible importance in the dry regions of the west. Such is not the case, for many localities, at least. Because of certain soil peculiarities, such as the common tendency for the soils of the drier regions to crack or crumble into a loose, fluffy condition on drying, erosion is exceedingly severe in many parts of the west, even in desert areas.

In the cattle country of west Texas and central New Mexico, numerous places were observed recently, where deep rich valley soil, representing the accumulation of ages, had been washed out largely or wholly, leaving behind an absolute waste. The washing that causes the destruction or extreme impairment of these valuable grazing lands usually has its beginning in those places where the vegetation has been removed and the ground surface broken, as in cattle trails and bedding grounds, roadways, diversion ditches and prairie-dog towns. In one valley area of the Davis Mountain region of west Texas a thousand acres of former good grazing land was found to have been almost completely destroyed as the result of washing started in a prairie-dog town, where the vegetation had been eaten and the ground punctured with holes.

Large grazing areas of the west have suffered seriously from erosion induced by overstocking. In regard to this growing menace to the ranges, W. R. Chapline, the range expert of the Forest Service, says:

PLANTING RUBBER TREES IN SUMATRA

ON EXCAVATED TERRACES. SOME OF THE RUBBER PLANTATIONS OF THE EAST INDIES TAKE BETTER CARE OF THEIR LAND THAN MOST OF THE FARMERS OF THE UNITED STATES.

As early as 1890 range grazing lands were stocked to their capacity, while some were already overstocked. The continued overstocking over numerous areas reduced the carrying capacity, both by cutting down the quantity of forage produced and by increasing erosion of the productive surface soil. Reduction in grazing capacity necessitated decreasing the numbers of livestock, with resulting excessive per head investments in lands and improvements and uneconomic production. Furthermore, the erosion has carried millions of tons of silt from the ranges into irrigation and other reservoirs; the floods have ruined many farms by a blanket of sand and gravel, and have destroyed roads and other works. The financial loss to the farmer has been as great as that to the live-stock producer. The greatest loss has doubtless been the lowered productivity of the soil on the ranges and the difficulty of re-establishing a satisfactory protective covering.

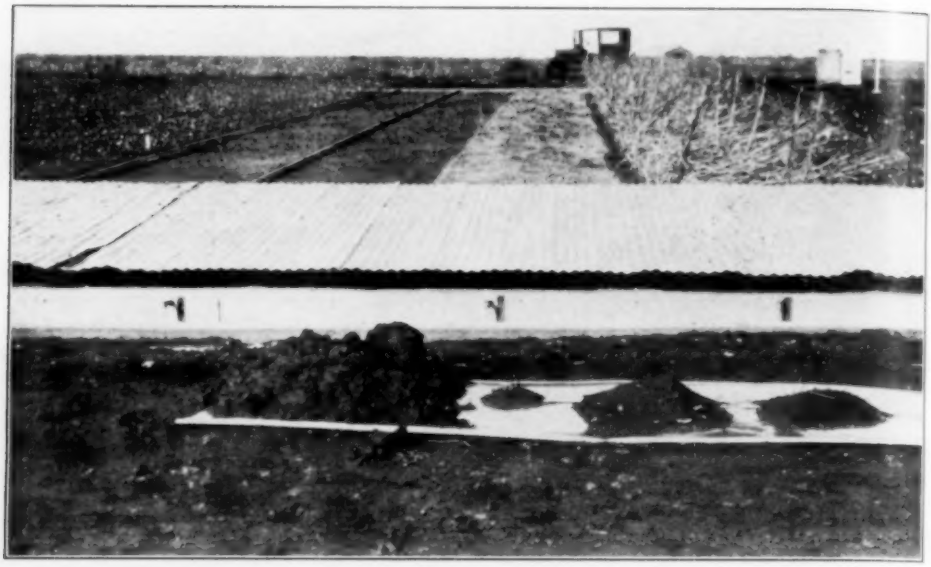
STAND OF SHORTLEAF PINE

ON ABANDONED FIELD IN EAST TEXAS. THIS IS THE BEST CROP FOR SOME MILLIONS OF ACRES OF EROSIVE LAND IN THE SOUTH.

Recently a layer of infertile sandy material swept out from a burned-over hillside in the southwestern United States was deposited over an orange grove of great value. The trees quickly showed distressing injury, some of them dying. It became necessary to rake the infertile detritus back from the base of the trees, wherever the deposit was less than a foot thick, and to haul it out of the grove where it was deeper. It is said to have cost a hundred thousand dollars, or twelve hundred dollars per acre, to remedy the distressing situation, which was brought about as the result of a single rainy period. The grove can not stand another such disaster, as the owners see it. And there will be many other farms in many other parts of the nation that will not be able to stand the cost if we do not do a great deal more than we have done in the past to check the evils of erosion. Writing of the

THOROUGH DISSECTION OF A PIEDMONT COUNTY BY DRAINAGE LINES

INNUMERABLE TRIBUTARIES TO THE STREAMS SHOWN EXIST IN MANY PARTS OF THIS COUNTY IN THE FORM OF EROSION GULLIES.



THE EROSIONAL WORK OF ONE RAIN

i.e., WASH-OFF OF SURFACE SOIL MATERIAL FROM VERY MILD SLOPE AT THE SPUR STATION, TEXAS, SHOWN IN PILES ON WHITE CLOTH OF FOREGROUND, LEFT TO RIGHT: FIRST, FROM BARE-GROUND PLOT, WEEDS REMOVED WITHOUT DISTURBING THE SOIL; SECOND, FROM GRASS PLOT; THIRD, FROM GRAIN-SORGHUM PLOT; FOURTH, FROM COTTON PLOT. EROSION ON THIS 2-PER CENT. SLOPE AMOUNTED TO FORTY TONS OF SOIL MATERIAL PER ACRE WITH TWENTY-SEVEN INCHES OF RAINFALL.

wastage, Mr. G. E. Martin, of the Oklahoma extension service, says: "The loss constitutes a most serious drain upon the agricultural industry. It is very unlikely that any other industry could suffer such severe losses and survive."

Putting the matter in more tangible terms, in pounds of plant food wasted and in values with the dollar mark prefix, it is found that the value of the plant food contained in the soil washed out of the fields and pastures of the

SOIL-SAVING FIELD TERRACES

IN THE PIEDMONT OF NORTH CAROLINA. ON SOME SOILS THESE SOIL CONSERVATION EMBANKMENTS CAN BE CULTIVATED OVER ABOUT AS WELL AS ANY OTHER PART OF THE FIELD.

United States every year, chiefly from the former, exceeds two billion dollars, on the basis of chemical analyses of the soils of the country, and the value of the principal constituents (phosphorus, nitrogen and potassium) carried in the cheapest forms of commercial fertilizers. Of this sum there is evidence that at least two hundred million dollars represents a tangible, annual loss to the farmers of the country; while a considerable part of the remainder is a loss to posterity, since the marshes it goes to build at the mouths of rivers can scarcely be used for some geological eons to come, and the alluvial lands covered need no additional material.

The plant nutrients contained in this wastage exceeds one hundred and twenty-six billion pounds. In other

GULLIES IN THE "BROWN LOAM" COUNTRY

IN SOME COUNTIES IN THE EXTENSIVE AND IMPORTANT SOIL REGION OF THE "BROWN LOAM" (LOESS SOIL) COUNTRY, THAT EXTENDS FAR UP THE MISSISSIPPI-MISSOURI RIVER SYSTEM, AGRICULTURE HAS BEEN LARGELY DRIVEN OUT OF THE UPLANDS BY DISASTROUS GULLYING. THE GULLIES HAVE RIPPED TO PIECES VAST AREAS OF THESE PRODUCTIVE SOILS, WHICH COULD HAVE BEEN SAVED BY TERRACING THE GENTLER SLOPES AND LEAVING TIMBER ON THE STEEPER ONES. THIS PECULIAR TYPE OF EROSION IS THE RADIAL-EXTENSION TYPE, WHICH EXTENDS EQUALLY IN ALL DIRECTIONS, COMPLETELY DESTROYING THE SOIL AND LEAVING INFERTILE CLAY THAT HAS LITTLE VALUE EVEN FOR TREES.

NORFOLK FINE SANDY LOAM SOIL

NEAR THE GULF OF MEXICO. SHOWING HOW SANDY SUBSOIL MATERIAL FLOWS OUT FROM BENEATH THE HEAVIER TOP-SOIL IN DITCHES.

words, the annual bathing bill of our agricultural lands in terms of plant food exceeds the net loss in the crops taken off by more than twenty-one times.

These figures are derived from minimum estimates of soil wastage, based upon the amount of suspended matter delivered by the rivers to tidewater each year, plus a small part of the soil material washed off sloping areas and temporarily stranded en route to the sea. It is known from analysis of river waters that a minimum of five hundred and thirteen million tons of suspended matter and of two hundred and seventy million tons of dissolved matter are yearly transported from continental United States to the oceans. The Mississippi alone takes care of four hundred and twenty-eight million tons of this traffic, in solids alone.

To those familiar with field conditions these estimates will be recognized as being absurdly small; but this point need not be discussed here.

VIII

By catching and measuring the runoff and washoff from a moderate slope, it was found at the Missouri Experiment

GRENADA SOIL OF NORTHEASTERN MISSISSIPPI

RUINED BY WASHING. THE TOP-SOIL GRADUALLY WASHES OFF DOWN TO THE COMPACT WHITE LAYER, THEN RAPID LATERAL WASHING TAKES PLACE, AND FINALLY THE COMPACT MATERIAL IS CUT THROUGH TO INFERTILE CLAY THAT BAKES ALMOST LIKE ASPHALT.

Station that for an average of six years forty-one tons of soil material were washed annually from one acre of land plowed four inches deep; and that 68 per cent. of the rainfall, amounting approximately to thirty-six inches per annum, was absorbed. From an area of the same soil and slope, covered with blue grass, a little less than .3 of a ton of solid matter was removed each year; whereas 88 per cent. of the rainfall was retained. In other words, grass land held back one hundred and thirty-seven times as much soil as the bare area and about 29 per cent. more of the rainwater that fell upon the ground. This rate of erosion would cause the removal of a seven-inch layer of soil from land of this kind, tilled four inches deep, in twenty-four years; whereas the removal of the same thickness from areas under grass would require 3,547 years.

ERODED HILLSIDES

IN DONIPHAN COUNTY, KANSAS, NORTHWEST OF TROY. ALFALFA, SEEDED LAST YEAR (1927), ON THE DARK PATCHES OF MIDDLE-GROUND, AND GRASS ON THE ASSOCIATED LIGHT PATCHES. THE FORMER IS SUCCEEDING FAIRLY WELL WHERE FROM FIVE TO SEVEN INCHES OF THE ORIGINAL SILT LOAM COVERING STILL REMAINS, BUT GRASS HAS DRIVEN OUT THE ALFALFA ON THOSE AREAS WHERE ALL OR NEARLY ALL THE TOP-SOIL HAS WASHED AWAY DOWN TO THE SILTY CLAY LOAM SUBSOIL (KNOX SILTY CLAY LOAM).

At Spur, in subhumid western Texas, experiments conducted for the purpose of determining the possibilities of storing moisture in the subsoil for summer crop use revealed the astounding fact that forty-one tons of soil matter were removed from one acre by one year's precipitation of twenty-seven inches, and this on ground of only two per cent. slope. A slope no steeper than this is not far removed from level ground, so far as the eye is capable of detecting. Of the rainfall, ground covered with buffalo grass retained 84 per cent., while fallow ground retained only 55 per cent. As the result of terracing the fields, much of the rainfall was stored in the subsoil, and the yield of cotton was considerably increased as a result.

The highly valuable loessial or wind-deposited soils of the Mississippi Valley if neglected, melt away with rain, almost like sugar, forming broad and deep gullies that invade the countryside with far greater desolation than that wrought by shell-fire, trench or mine upon the fields of France. The combined extent of land destruction during the World War was small in comparison with the evil work that has been

done by soil erosion in single localities in many parts of the United States.

IX

When the mellow topsoil is gone, with its valuable humus and nitrogen, that which takes its place usually consists of raw subsoil material, often stiff clay. This is less productive, less permeable to plant roots, less absorptive of rainfall and less retentive of that which is absorbed. The exposed raw subsoil, now called upon to function as soil, must in countless instances be improved for plant growth by incorporating with it vegetable matter and by loosening the compact material with increased tillage to allow ingress of air, that agent which with its supply of oxygen is so necessary for the conditioning of soil. Often largely increased amounts of fertilizer are required for satisfactory yields, and lime is needed to correct acidity or otherwise to improve the soil. All these things take time and work and money.

The writer owns land, where, as a boy, he hoed and plowed cotton on deep, mellow loam, from which fields every particle of the topsoil has been washed off down to the clay subsoil, in spite of all that has been done to save the land. To produce as much cotton per acre as these fields formerly gave, it now takes from six to eight hundred pounds of fertilizer per acre, as against two to three hundred pounds before the soil left on its journey to the sea. And this has happened upon neighboring farms, not merely in an occasional field, but in most of the fields. It has also happened in neighboring counties and in neighboring states.

NATIVE AGRICULTURE, PHILIPPINE ISLANDS

EVERY VESTIGE OF USABLE LAND EMPLOYED FOR GROWING RICE.

X

So long as rain falls upon the earth there is going to be soil erosion. The

DEEP GULLY HEAD-ON EXTENSION TYPE OF EROSION

GULLIES OF THIS KIND ADVANCE RAPIDLY BY THE HEAD BY REASON OF THE CAVING ACCENTUATED AT THIS PART OF THE RAVINE BY RAIN-WATER COLLECTED IN DEPRESSIONS.

process is as natural as the process of decay in a fallen tree. However, we need not concern ourselves with that slow type of washing that takes place on forested lands, provided these are not overgrazed and repeatedly burned; nor need there be much worry about areas well covered with grass, such as that which matted the prairies and much of the eastern plains region in the central part of the United States about two generations ago, *i.e.*, before these vast areas were broken to establish our wheat and corn belts. The evil part of erosion is that which, with the assistance of man and animals, exceeds the natural order of things by upsetting the normal equilibrium between the ground, on the one hand, and the vegetative cover and other stabilizing agencies, on the other hand. It is the excessive washing that has followed the removal of grass, trees and bushes, and the cultivation of steep slopes and lands of excessive vulnerability to washing, without making provision for assisting the disturbed bare soil to hold itself in place that must be dealt with, if the wastage is to be checked.

As a nation we have concerned ourselves exceedingly little about the matter. We have associations for the conservation of wild life, including the flowers, and for the preservation of the gowns of the Presidents' wives; we have established numerous experiment stations in every state for finding out how best to restore the plant food removed by crops, but only one to find out how to retain the twenty-one times greater amount of plant food removed by soil erosion, not to mention the whole body of the soil that goes along with the plant nutrients. But there are no associations for the preservation of the agricultural lands of the nation. We send ships to South America for nitrogen and to Germany and France for potash to replenish our fields, while unconcernedly watching billions of pounds of these materials flowing merrily away from the same fields in rushing rain water. We dig deep into the bowels of the earth searching for stored potash, while that in our soils is being swept away to the oceans.

It is not meant by this that the purchasing and mining of fertilizer materials are to be condemned. They are

A COASTAL PLAIN GULLY

THAT HAD ITS BEGINNING IN A FIELD CUTTING THROUGH WOODLAND.

BLANKET OF SANDY OVERWASH

WHICH MAKES THIS PART OF THE SANTA CLARA RIVER VALLEY, EAST OF SANTA PAULA, PRACTICALLY WORTHLESS. THIS STRIP OF RECENTLY DEPOSITED MATERIAL IS ABOUT ONE HALF MILE WIDE.

referred to merely as illustrations of the way nations having abundant resources use them freely, and too often with little thought about conserving them because the other way is easier and because habits generally are not corrected over night. We have accepted land wastage by erosion as something on the order of a natural process, even where its rate has been increased several hundred times by our own handiwork. We have in profound economic discussions referred, often with display of heated concern, to the removal of plant nutrients from the land by the long-continued growing of the same crop as an evil deserving the wicked names, "soil mining" and "soil robbery." We shall not object to this further than to say that soil mining by this process, bad as it often is, is a very small item compared with the operations of the other evil genius that we choose to designate soil erosion. And, too, we shouldn't overlook the fact that plants take out of the soil only the plant food, which can be restored; whereas the villain, wrathful water, takes the plant food and the soil that contains the plant food, which can not be restored.

XI

The erosional-débris discharged into streams does not diminish their volume. The suspended matter, the dissolved matter and the drag material rolling down the beds of the rivers in waves like

ROADSIDE CEMENT GUTTER

PARTLY FILLED WITH EROSIONAL DÉBRIS, AND BEING UNDERMINED BY EROSION, OJAI VALLEY, CALIFORNIA.

MOUNTAIN SLOPE AND VALLEY AREAS OF THE COSTA RICAN HIGHLANDS, WHICH HAVE BEEN IN CULTIVATION FOR NEARLY FOUR CENTURIES WITH PRACTICALLY NO RESULTANT EROSION, BECAUSE OF THE HIGHLY ABSORPTIVE CHARACTER OF THE SOILS.

sand-dunes, most of which comes from tilled lands, abandoned fields and overgrazed pastures, adds to the volume of floodwater very considerably. This is an obvious mathematical truth.

A feature of utmost importance in this connection is the largely increased rate at which water flows off those areas that have had their absorptive mellow topsoil washed off down to impervious clay, rock or incompletely weathered subsoil material. This, coupled with the erosional-débris swept into stream channels, has been the cause of increased floods in many rivers, of increased swampiness over vast areas of bottom land and of excessive surface deposition of comparatively infertile sand, gravel and cobbles over productive alluvial plains and lower slopes.

Thus erosion works in the quadruple rôle of increasing the amount of sediments discharged into the streams; of reducing the agricultural value of the eroded uplands; of damaging or ruining alluvial bottoms by overwash and by increased swampiness; and of causing rainwater to flow off impervious washed areas much faster than formerly. This is a serious indictment of the process. But it is none too serious, and unless we do very much more in the future to check the evil scourge than we have done in the past, it can be said now, as previously stated, and without any fear of subsequent punishment for false prophecies, that this country is really but upon the threshold of disastrous soil erosion. This prediction is based upon the fact that subsoil material usually washes faster than surface-soil material and is always more difficult to conserve with the known implements of remedial measures.

XII

What is needed most to conserve soil and soil fertility is a greatly increased use of hillside terraces as a means of slowing down erosion. In the general neglect of studies relating to the fundamentals of the problem, the best thing to do with some peculiar kinds of land has not yet been determined. It is not known, for example, what type of terrace is best suited to a considerable number of these peculiar soils, or, indeed, whether or not any kind of terrace will

THE BEGINNING OF A GROUP OF GULLIES

BY RUNNING THE CROP ROWS UP-AND-DOWN SLOPES GULLYING IS ENCOURAGED, AND OFTEN FIELDS ARE WASHED AWAY UNDER THIS CONDITION BY A SINGLE TORRENTIAL RAIN.

HILL SLOPE NEAR SANTA PAULA, CALIFORNIA

THE EROSION HERE IS TERRIFIC. EVERY YEAR DURING THE RAINY SEASON LARGE AMOUNTS OF MATERIAL ARE WASHED FROM THESE BARE PLACES AND SWEPT OUT OVER HIGHLY PRODUCTIVE VALLEY LANDS TO THEIR DECIDED INJURY. HERE IS A PROBLEM FOR THE PLANT SPECIALIST, *i.e.*, TO ESTABLISH SOME SOIL-HOLDING VEGETATIVE COVER OVER THE ERODING AREAS. PROBABLY OVERGRAZING AND FIRES HAVE CONTRIBUTED TO THE DAMAGE HERE.

save some of them. But it is known that broad embankments, of the Mangum terrace type, are highly effective as conservers of both soil and soil moisture in many parts of the country. In the less steeply sloping fields these embankments can be cultivated over about as easily as any other part of the field. There will be, however, conditions of slope, soil and climate where other forms of embankments must be resorted to for effective results, and no doubt it will be

IN THE UPLANDS

AGRICULTURE HAS BEEN DRIVEN OUT OF THE UPLANDS OF SOME COUNTIES IN THE LOESSIAL REGION BY EROSION. GULLIES AND BROAD WASHES HAVE SO CUT THE LAND TO PIECES THAT ONLY SMALL AREAS OF GOOD SOIL ARE LEFT IN MANY LOCALITIES.

necessary under some conditions to reenforce these with grass or vines or else to resort to expensive wall-terraces, such as have saved much land in the Mediterranean Basin and in Palestine for more than two thousand years.

Terraces are very practical things. They can be constructed with plows, scrapes and drags at those times of the year when farm work is not pressing. They function much after the manner of hedge-rows and fences in catching and holding soil and moisture coming from slopes above. Being adjusted to slope and soil and having the form of an embankment, they are much more efficient, as a matter of course. They must be laid out correctly, however, or costly breaks will occur. Farmers can be taught how to do this by county agricultural agents, when the latter have been taught how to do it themselves, and that is what is being done in many parts of the south.

For several generations terracing of land has been a common practice on many farms in the southeastern states. At the present time they are being built at a rapid rate in Texas and Oklahoma. In the former state five hundred thousand acres of land were terraced in 1927 under the leadership of one hundred and seventy-five county agricultural agents. The 1928 program for Texas calls for the terracing of one million acres. Even the Federal Land Bank, of Houston, has its terrace expert. If a farmer asks for a loan on his land, the expert looks over the ground to see if it needs terracing. If it does, the work must be attended to before the loan is made. If the farmer doesn't know how, the expert goes out and shows him how to do it.

Chambers of commerce, knowing that good yields and productive lands usually mean farm prosperity and that prosperous farmers mean prosperous communities, are very actively pushing this method of land conservation in Oklahoma and Texas. Most of the county agricultural agents in these states and in many of the counties of southern Mississippi and other southeastern states are busy with programs of saving the soil.

In north-central United States, however, probably not one acre in a hundred

CREEK BOTTOM

COVERED BY SAND WASHED DOWN FROM THE HILLS. THIS AREA WAS BURIED TWENTY FEET DEEP IN FIFTEEN YEARS. IT IS A STRIP OF GEORGIA ALLUVIAL LAND.

thousand is terraced. Generally, the farmers of that vast territory know nothing of this highly efficient embankment system of holding the soil; many of them have not even heard of it.

There are many sloping fields, however, that can not be protected by terraces. Some types of soil wash too readily for cultivation and should not

LAND PERMANENTLY DESTROYED BY SHEET AND GULLY EROSION. THIS IS SUSQUEHANNA CLAY OF THE GULF COASTAL PLAIN, A SOIL WHICH IS PECULIARLY SUSCEPTIBLE TO DESTRUCTIVE EROSION.

be tilled under any circumstances. In the Appalachian Plateau fields are still being cleared where the farmers know that but from one to three crops can be grown before the soil washes away.

XIII

We need to know more about erosional processes. As yet we have measured the rate of washing on but three important types of farm soil of the hundreds of types in the country. We do not even know as yet at what degree of slope cultivation should cease and the land be put into use for grass or trees. We must have these facts. They are fundamental and necessary to both the engineering and agronomic side of handling the problem of land conservation.

When the farmers know what to do they will act. They must have assistance and demonstration of methods, and done to insure the employment of good methods only, methods duly adjusted to varying slope and soil for all the important types of farm land. Terracing, let it be understood, will pay its own way many times over when the farmers have been brought to know what land can be economically protected in this way and how to do the job efficiently. Other engineering means of land protection must be sought in order that gullies may be stopped and filled and that the more vulnerable soils, upon whose steeper slopes terraces have failed, may be saved. Grass and trees must be more extensively grown on the steeper and less stable soils, and crop rotations must be practiced that include soil-improving and soil-saving grasses and legumes.

PROVIDENCE CAVE

SEVEN MILES WEST OF LUMPKIN, GEORGIA. THIS GULLY STARTED FROM THE DRIP FROM A BARN. NOW THE BARN IS GONE AND A LARGE SLICE OF LAND. IN PLACES THIS GULLY IS MORE THAN ONE HUNDRED FEET DEEP. IN THE COUNTY WHERE IT OCCURS SEVENTY THOUSAND ACRES OF FORMERLY TILLED LAND HAVE BEEN RUINED BY EROSION.

EARLY STAGE OF LAND DESTRUCTION BY EROSION ON LAND OF STIFF CLAY SUBSOIL (SUSQUEHANNA TYPE).

XIV

Finally, we may as well recognize the fact that the evils of erosion are not a matter for future concern only. Thousands of farmers have suffered and are now suffering from the impoverishing effects of rainwash upon the soil. Our better lands have already been put into agricultural use; we are now taking up the inferior grades. Erosion is adding to the area of submarginal and destroyed lands. By increased use of fertilizers and soil-improving crops and with more expensive tillage and abandonment of the more severely washed fields, acreage yields have been fairly well maintained in many farming regions. But the increased cost has brought financial ruin to many farmers.

The viewpoint of business men as to the importance of the problem is clearly revealed in the report of the Business Men's Commission on Agriculture given in a recent publication of the National Industrial Conference Board, which says in part:

> The progressive deterioration of our farm lands in this process (erosion) has . . . meant increased difficulties for agriculture, to say nothing of the national injury involved. . . . In the long run erosion is of superlative importance, but it receives comparatively little attention owing to the fact that yields are not greatly diminished until the humus layer is well on the way to exhaustion. The depletion of essential plant foods, through cropping, leads to a cumulative and readily recognizable decline in yields, but soil wastage by erosion, which every year carries away a layer of the surface soil on all areas devoted to cultivated crops, does not appear clearly until the soil grows too thin to furnish adequate nourishment to plants. Unlike the exhaustion of individual elements in the soil, this damage is irreparable, although in a large part it can be prevented by proper methods of cultivation and drainage and by flood control, together with reforestation. . . .
>
> The unavoidable result of this deterioration of the soil is lower yields per acre than would

FORMERLY GOOD FARM LAND UTTERLY RIPPED TO PIECES BY EROSIONAL GULLIES. THIS LAND CAN NOT BE RECLAIMED. IT SHOULD HAVE BEEN SAVED AND COULD HAVE BEEN. MUCH TOO LITTLE IS BEING DONE IN THE UNITED STATES TO PREVENT THIS KIND OF LAND WRECKAGE. THIS IS IN THE REGION OF "BROWN LOAM" (GRENADA SILT LOAM) SOIL THAT COVERS MUCH OF THE UPLANDS BORDERING THE LOWER MISSISSIPPI.

prevail without this factor. The increases in yield made possible by more scientific producing methods are in part wiped out by the progressive exhaustion of the soil, and agricultural costs are therefore steadily increased. Under existing conditions it often may not pay the farmer to use his land conservatively. This is an intricate matter of prices and interest rates, but whatever may be the facts with regard to the costs involved, most farmers seem to be dealing with the question in a manner which involves ultimate exhaustion of the land.

XV

Not a very cheerful picture of our American system of land usage has been painted in this article. With past performances as a background, there is exceedingly little upon which to build a glowing account of our stewardship of the land. However, with the recent soil-conservation activities in Texas, Oklahoma and several other localities, there is good cause to look for a very large expansion in the practice of these commendable methods in the near future, especially if we perform our national and individual duties of helping the farmers.

KNIFE EDGES

FORMED BY EROSION ON GOOD TENNESSEE SOIL.

SHARK FISHING IN THE WEST INDIES

By O. W. BARRETT

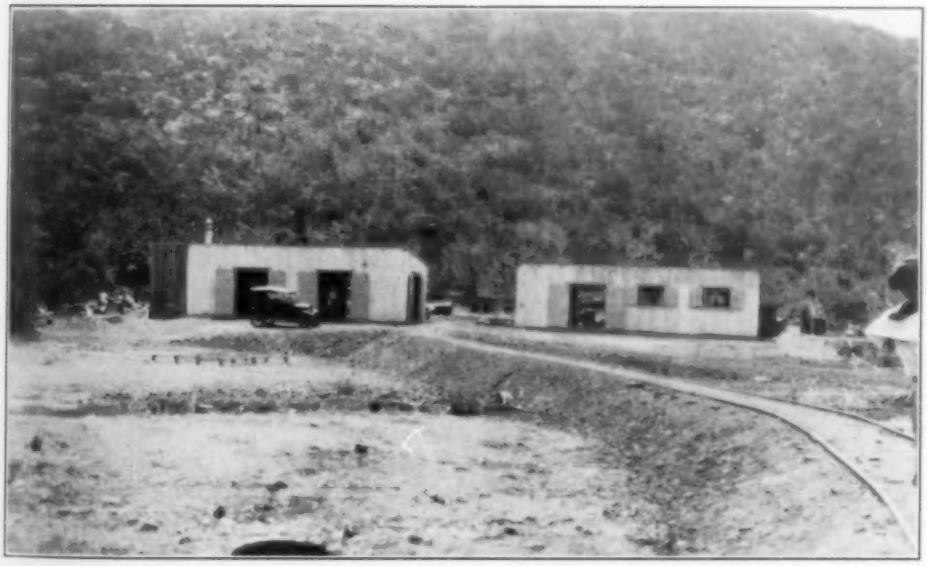
AGRICULTURAL DIRECTOR, DEPARTMENT OF AGRICULTURE AND LABOR,
SAN JUAN, PORTO RICO

Of beautiful leathers there is no end, but none better, it seems, than shagreen. For several centuries the bookbinders and curriers have recognized the excellent qualities of shark-skin leather, but only in the last few years has the general public had an opportunity to get the handsome purses, bags and shoes which are now made from the hide of that much hated denizen of the deep.

So many improvements have been made in the *modus operandi* of catching sharks and in utilizing their by-products that the outlook for considerable commercial expansion in that branch of industry is now assured.

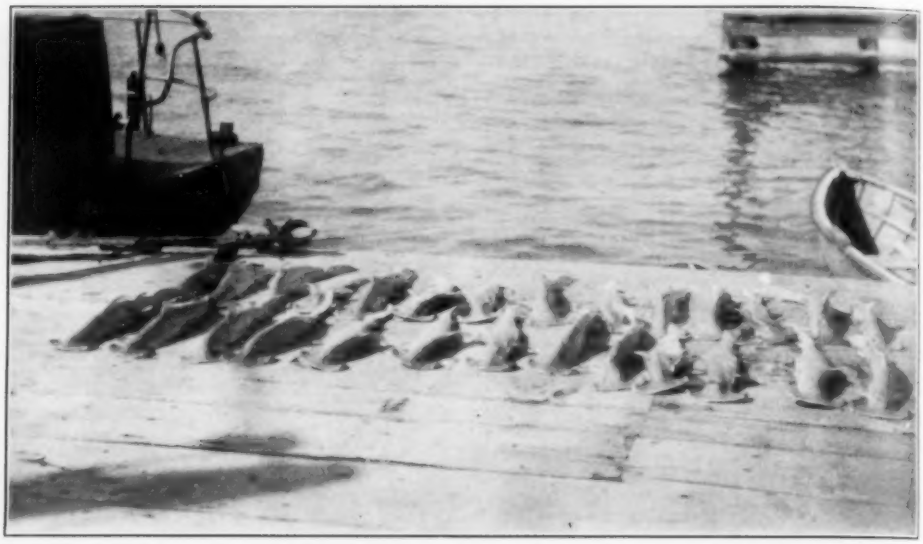
Florida has had two or three successful shark-fishing stations for several years, and some desultory fishing has been done in various West Indian Islands, one plant in the American Virgin Islands having spent a large amount of money in installing a modern factory with expensive equipment. There are also projects under way for the establishment of several other stations in Porto Rico, Santo Domingo, Cuba, the British Virgin Islands and Dominica. Most of these West Indian stations will probably not be outfitted to utilize all the shark, but the hide, fins and liver oil can be saved without the installation of special apparatus for drying and grinding the flesh.

The writer, having had some experience in several tropical American countries, believes that the following system will be found most economical: a small building located within reach of fishing boats and so situated that no complaints



AN UP-TO-DATE SHARK FACTORY

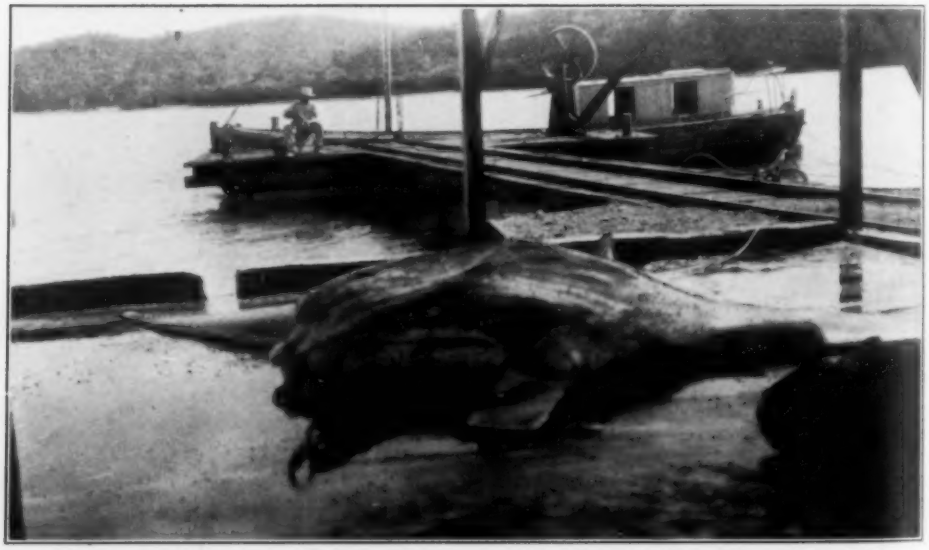
THE HIDE HOUSE IS AT THE RIGHT, AND THE OIL AND MEAT MEAL HOUSE ARE TO THE LEFT.



—*Courtesy of W. E. Young*

THE TWENTY-SEVEN YOUNG OF A THIRTEEN-FOOT HAMMERHEAD SHARK

on the part of the public can be made on account of the odors which sometimes are objectionable near such a plant; the fishermen bring their sharks to the plant and sell them at a moderate price—just enough to pay for their trouble; the hides are stripped off and salted down; the fins are removed and



—*Courtesy of E. D. Bellows*

A YOUNG MANTA

OR DEVILFISH, TWELVE FEET IN WIDTH. THE RIGHT CEPHALIC FIN HAD BEEN LOST, PRESUMABLY IN A BATTLE WITH A SHARK. THE SHARK BOAT, PIER AND LANDING DERRICK AT RED HOOK, ST. THOMAS, ARE IN THE BACKGROUND.

—*Courtesy of C. E. Daniel*

"TIGER" HEAD. NOTE THE NOSTRIL FLAPS

dried in the sun; the livers are rendered, preferably by the bain-marie system or in steam-jacket kettles. The plant can hardly lose any money on the hides, fins and oil obtained by this system; and if circumstances so warrant the plant may gradually expand its operations, installing a drying oven for utilizing the flesh of the sharks and other fish, both for human consumption and for poultry and pig feeds; putting out its own nets and trawl lines in addition to buying sharks and other marine materials from the fishermen would follow in this elastic policy of operation. A plant could be run with only two or three laborers and one superintendent to give a part of his time to the enterprise; or the same unit could be expanded into a factory turning out a ton or more per day of fish meal besides a hundred dollars' worth of hides, fins and oil.

Floating factories are also being tried out, and they may succeed in partly sheltered regions, like the Gulf of Mexico, where schools of many kinds of fish can be "worked" with nets and launches; kettles, presses and steam dryers are rigged up on board so that very little manual labor is required.

Another important factor—and, perhaps, in future work this will prove to be even more important than any kind of shark fishing *per se*—is the making of dried fish fillets. Thick slices of clear white flesh can be taken from the sides of large fish, like the groupers, snappers and the larger kinds of mackerel, as well as sharks, and either promptly frozen or dried thoroughly in a dehydrator. When put in paraffin-paper packages, these "cutlets" are becoming very popular and are a great boon to the housewife who never, under the most favor-

A TWELVE-FOOT GRAY SHARK

WRONGLY CALLED TIGER. NOTE THE NOSTRIL AND TEETH.

GREEN TURTLES FOR SHARK BAIT AT A SHARK PLANT

able circumstances, likes the work of "dressing" a fish herself. Prepared in this way the major portion of the edible parts of the larger food fishes can be saved and put into form for long-distance shipments, the price of these dried or frozen cutlets more than equaling the value of the entire fish as ordinarily placed on the market. The skin, fins and heads when digested in an autoclave yield glue, for which there is always a fair demand; the remainder of the fish dried and ground becomes high-grade poultry feed or fertilizer.

Every shark plant will, of course, have its pressure cooker for extracting the oil from inedible species of fish and from fish refuse; it will also save the heads, claspers and tails of sharks—which are now wasted—for glue. No farmer likes to have even 1 per cent. of oil in his fertilizer, although, of course, a little does more good than harm if promptly used in poultry feeds. In this connection it is interesting to note that cod-liver oil has proved to be the "missing link" in poultry raising; up to a few years ago there was something lacking in the poultry feeds, now a spoonful of the oil every few days in the pan of mash serves to keep up the vigor of the fowls.

A 150-POUND LEOPARD RAY
THE SHARK'S FAVORITE FOOD. NOTE THE RINGS AND SPOTS FORMING A BEAUTIFUL PATTERN.

A TYPICAL WEST INDIAN SHARK BOAT

There are hundreds of suitable sites around the Greater and Lesser Antilles, to say nothing of the Caribbean and Gulf Coasts of the mainland, where from three to six sharks on an average may readily be taken every day in the year without materially affecting the supply.

There is no more attractive work and the industry would not only give employment to a very deserving class of people but would probably yield better profits on the capital invested than would any other similar enterprise.

In the Sulu Archipelago of the southern Philippines there are several places

where Moro fishermen make a good living merely by taking the fins of certain species of sharks and drying them for the Chinese trade. In some of the Arctic regions the Eskimos also do well at catching sharks simply for the oil of their livers, and this system has been duplicated in various other regions, notably off the West Coast of northern South America, where the basking shark may be taken at times in large numbers, each fish yielding from forty to over one hundred gallons of oil from the large liver.

There are other localities where sharks are taken for their skins alone. Factories are now being installed, however, wherein practically all parts of the shark will be utilized. The skin will be the principal item and its value should average about two dollars for "general run" grays of seven to nine feet; that from large "tigers" and hammerheads may be worth five dollars or more if the skin is in good condition. Fortunately, the skin of the commonest species, the "gata" (cat), or nurse shark, is the most valuable for shoe leather; its tensile strength is six to ten times that of ox-hide.

The second item in importance will be the liver oil. At present the price of shark-liver oil is very low because it has to compete with ordinary fish oil in the open market. This status is gradually changing, due to the fact that poultry raisers and others are recognizing the fact that the oil from shark livers ranks with cod-liver oil as a cheap and safe source of vitamins; all the principal vitamins A, B, C and D, are contained in shark oil, D being the most important, perhaps.

The fins come third in importance in the shark raw materials. The price varies greatly from a few cents apiece in case of the common nurse sharks of tropical waters to two dollars or more per pound for the gelatinous fins of the sawfish shark.

The last, but in some ways the most important, part of the shark to be considered in the modern plant is the meat; the meal, made by thoroughly drying the flesh and then grinding it, is a first-class feed for poultry and pigs. Strange to say, little effort has been made to save the meat of sharks in most localities, although one or two factories in Florida have successfully sun-dried large quantities of shark meat for human consumption; the Belgian Congo consumes very large quantities of salt shark meat. One out-of-the-way place in Porto Rico has for years been producing quantities of dried shark meat in competition with salt codfish, one of the principal imported foods of the island; the fins, livers and even hides at the said place are thrown away and only the large pieces of firm, boneless, white meat running from the shoulder to the middle of the body are removed and hung on wires to dry in the sun and wind—there being practically no rain at any time of the year in that locality. Fresh shark meat is commonly sold in the markets in most Antillean seaports, and its popularity seems to be increasing.

Instead of expensive and complicated vacuum dryers which have been used for this purpose, the shark meat merchants of the future will probably use some form of steam-pipe hot-air oven dryers. In this apparatus the meat, cut up in chunks, or, if for human food, in fillets, is put into wooden trays having galvanized-iron wire-mesh bottoms; and these trays fit into a huge box-shaped oven which is heated by horizontal coils of steam-pipe placed in five or more tiers between the trays. By keeping the temperature in the oven below 180° F. the vitamins in the meat are largely retained and the very high protein content is saved. Probably no other food product in the world is so rich in protein as shark meat meal; whereas dried blood and the best forms of tankage contain only about 60 per cent. to 70 per cent. protein, this

shark meal contains 75 per cent. to 91 per cent. In fact, it is so rich that it is now being used as a poultry tonic, and thus it stands outside of the class which is represented by ordinary slaughter-house tankage and "scrap" meal from the fish canneries and fish-oil factories.

Three plants for the manufacture of fish meal and fish oil are now being installed, one in Maine, one in Florida and one just over the line in Lower California; the latter factory will probably be one of the largest of the kind in the world, and will have a capacity of ten tons of meal per hour, according to reports.

Improvements in the methods of catching sharks are gradually being worked out. The most efficient method of capture is the set net. A net, from three hundred to five hundred feet in length, is stretched across areas where sharks are known to run, the bottom edge being anchored and the top edge buoyed by floats. Most sharks, when attempting to go through the net, get the strands, which are about twelve inches apart, caught in their gills and, strange to say, this soon causes them to "drown."

Trawls are also used: large specially tempered steel hooks, mounted on chains attached by swivels to the main line, are placed at intervals of a few yards along this trawl line. When properly baited and well set a good trawl line may catch from three to nine sharks at a setting; the trawl should be taken up every few hours in order to prevent the sharks caught on the hooks from being attacked by other sharks. New kinds of shark hooks are being tried out: it requires a high grade of steel to hold a one thousand-pound fish without breaking or straightening out.

In many places it is possible to harpoon sharks from a launch or rowboat; and on the east coast of Nicaragua the writer has seen sharks harpooned by a native standing in the surf; one man usually can pull in a seven-foot specimen, but two are needed for an eight-footer. In some places large numbers of sharks have been taken by the rather reprehensible method of baiting certain areas with fish offal and when the sharks which are attracted thereto are massed around the spot a stick of dynamite is thrown into the school and the stunned sharks are then lassoed or harpooned as they float, white bellies up, on the surface.

A Porto Rican shark fisherman has perfected a killing lance which makes it safer for the fisherman to handle these half-dead but very dangerous animals. The peculiar-shaped lance attached to a stout bamboo handle enters one of the gill slits in the side of the neck, and a twist of the wrist severs the main artery in the throat.

Another very interesting method of catching sharks has been in use on the south side of Porto Rico, where the nurse shark comes to breed in April, May and June around the reefs and in the lagoons. Men armed with ropes, clubs and "machetes" wade out into the shallows where the sharks are congregating and at that time they have little difficulty and practically no danger in taking large numbers of these animals, which are then hauled away in trucks and used as fertilizer in nearby fields.

It is a remarkable fact that after so much study has been put on ordinary fishes there should be such a lack of knowledge concerning the shark fauna of these tropical localities. We are just beginning to learn that there are not merely three or four species, as formerly believed, but actually ten or a dozen distinct commercial kinds of sharks, which inhabit the waters of the West Indies as well as the East Indies. Four or five of these species are more or less common throughout the year around the Antilles, while others are occasional visitors that come in from deeper waters to breed on the reefs and in the bays at certain periods.

The two commonest forms in tropical American waters are the nurse (*Ginglymostoma cirratum*) and the blue gray and dusky sharks (*Carcharhinus* and *Carcharias* spp.). There seems to be only one kind of the former, while there are at least three of the latter group. The so-called "tiger" (probably a *Carcharhinus*) is also common but never dependable—he is a routsabout traveler, while the gatas are reliable stay-at-homes and the grays are respectable middle-class folk. The sawfish (*Pristis pectinatus*), so common around Florida, the Nicaraguan coast and along northern South America, is strangely absent or very scarce in the Antillean regions. The hammerhead (*Sphyrna zygaena*) is a queer old fellow with many good qualities, when he can be found—and where; his hide is not so tough as that of the gata, but there is usually much more of it—being two or three times longer.

Related to the sharks, but of very different habits and shape are the rays. One of the commonest and most widely distributed fish in the Tropics of both hemispheres is the leopard ray, or chucho (*Aëtobatus narinari*). This excellent and very beautiful food-fish lives on the bottom at a depth of from two to five fathoms and eats mollusks and other marine animals which inhabit the ocean floor. The body of a ray is roughly triangular in shape and flattened like a flounder; the tail is reduced to a sort of whip which, however, may attain a length of six to ten feet or more. On account of their habit of lying half concealed in the mud, the rays have adopted a special manner of breathing: the water is taken in through circular apertures on the upper surface just back of the head and is expelled through slits on the underside of the body. The flesh of the chucho is of excellent quality, and it should be dried or frozen in fillets for human consumption. Its skin, covered with grayish-blue circles and spots, will some day be very popular.

The king of all rays is the eagle, or manta ray (*Manta birostris*) which is fairly common throughout the Caribbean and Gulf of Mexico. This so-called devil-fish attains a spread between the tips of the so-called "fins" of twenty-three and one half feet or more, the thickness of the body of such an animal, however, being only about three and one half feet. The weight of these large rays is about double what it appears. A small chucho of only five feet in width tips the scale at over 150 pounds, while a full-grown manta would probably weigh three or four tons.

In both sharks and rays there are no small bones as in ordinary fish—not even in the fins; the shark backbone is of a brilliant white color and when properly dried and held straight by means of an iron rod run through its center this object makes a very interesting and deservedly popular cane; the joint sculpture is decorative and the brilliancy of the ivory is remarkable.

The teeth of the common shark are unlike those of any other animal in the world; being composed of nearly pure enamel they are practically indestructible and their astonishing abundance in certain geological strata gives proof of the quondam great abundance of sharks, some of which must have attained a length of eighty feet in the Devonian era.

By the way, mounted on pieces of turtle shell, these shark teeth make excellent watch-fobs; their indescribable shape, brilliant white color, and serrate, curved edges make very attractive ornaments.

After some twenty years of experience with sharks the author has only just recently learned that a shark's tooth is a three-bladed razor: the glass-like enamel on the edge of each finely serrate denticle on all of the three sides of the tooth will cut a hair, just like a piece of glass. Incredible as it may seem, it is possible to scratch glass with the serrate edge of a

shark's tooth; it would appear, therefore, that shark-tooth "enamel" is the hardest animal substance in the world. The Boy Scouts are going to have some fun with their shark-tooth watch-fobs, which we understand are given away with each pair of shark-skin shoes.

There is a mystery about the shark's digestive function; the stomach is better than that of most fishes, the pancreas is good, the liver is excellent and serves not only to aid the gastric action but also stores up fat to carry the body over periods of food shortage; but when we look for the intestine we find only a complicated spiral valve-like organ and an excessively short, thick-walled tube—only two or three feet long in an eight-foot shark, while the alimentary canal of a porpoise, of the same size and living on just the same sort of food, measures over seventy-five feet in length.

With the possible exception of some of the turtles, for instance, the land tortoises of Tropical America (which are in some countries fattened up on sweet potatoes, their enlarged livers then constituting the famous dish, maracoy ragout, than which there is none better in the whole wide world), there is no liver so large in proportion as that of the common gray shark. A shark seven feet long and weighing about two hundred pounds has a liver, usually in two or three long lobes, which practically fills the entire abdominal cavity and may weigh twenty to thirty pounds. The gall bladder, however, is comparatively small. The oil content is so great that even the heat of the hand starts the oozing of the oil.

There is also a deplorably large shadow zone around our knowledge of sharks' breeding habits. Why do some sharks lay large four-cornered eggs while others give birth to their young in quasi-mammalian style—nourishing the sharklets within the female's body with a milk-like substance so that they are able to swim away on their own power at birth? In the shark and ray systems of reproduction all the eggs are fertilized—a much more economic arrangement than that which obtains in the case of nearly all other groups of fishes.

Coming back to the original point, the peculiar grain and sheen of shark leather, curried or uncurried, make it especially adaptable for cigarette-cases, purses, ladies' bags, belts, book-bindings, etc., while the regular-grade leather is now made up into shoes; these seem to outwear any other kind of leather. Shark leather does not scuff like other leathers. Its surface never checks, cracks nor "roughs up," and it seems to endure wetting and drying better than bovine leather. Formerly it was very difficult to work shark skins due to the fact that in most species there are flakes or spicules of lime embedded in the outer layer of the skin. So rough is this outer skin (sometimes called the "shagreen") of some species of sharks that it may be used in polishing wood or metal in place of sandpaper. A new patent "acid" process, however, removes the lime and leaves the skin pliable without destroying the peculiar "pattern" of the surface and its pleasing luster.

The color of shark leather varies greatly from a grayish or pale-brownish shade to a dark greenish or almost black color. By varying the kind of tanning material the shade can be changed artificially to meet the most fastidious public taste. We have long been accustomed to alligator leather, which has a much bolder "pattern" than that of the shark, but lacks the wonderful luster. Lizard skins have been popular for purses and small bags for years, and long ago the Japanese learned how to prepare the skins of large toads for such purposes.

Instead of slowly drying the fins on racks in the sun it is recommended that they should be quickly and completely

dried in hot-air ovens. When the moisture content is brought down to around 10 per cent. these fins can be packed in boxes, barrels or bales and, if protected from the weather, can be shipped halfway around the world without deterioration. An expert Chinese cook, given two days for the work, can make a soup from shark fins which can not be excelled; the gelatinous rods become quite transparent and the peculiar delicate flavor is even better than that of the famous bird's-nest soup, for which Chinese epicures pay exorbitant prices; fin soup, particularly the "boon-leong-sit" variety, may be worth five Hong-kong dollars per bowl: it is supposed to possess highly invigorating qualities.

England now seems to be vying with America in the utilization of shark meat as well as leather; it is reported that one to two hundred tons of "rock salmon," or shark meat, are consumed daily in the London district. By the way, the flavor and texture of shark meat is somewhat like that of halibut. The writer regards young hammerhead as the best food shark.

Now that we have learned how to obtain sharks in large quantities much more cheaply than heretofore the public should in the next few years have an opportunity to obtain several times as much shark leather as in the past.

It is difficult to explain just why sharks are at present so much in the limelight; but it may be that there is a decided pull, so to speak, both on the part of buyers of shark leather and the users of shark by-products, such as liver oil, meat meal, etc., and also a push on the part of the producers; they are now anxious to *sell* the sharks which they have been catching and throwing away. Logically, a purse or hand-bag with the distinctive "shark sheen" will outsell the ordinary article anywhere; and very naturally the fishermen are tired of pulling up their hooks and finding that the sharks have taken bites off the fish on the hooks, broken their fish-traps and frightened away the best kinds of food fish; and when they can sell one of these murderous marauders for a dollar or two at the factory instead of throwing him back for his cannibal brothers to eat—then the business begins to grow.

Finally, the main point to consider is this: we now have ways and means of utilizing sharks commercially, we are learning how to take them cheaply, and we know that by removing them from the sea we are directly saving other fishes. And while it is hardly possible to successfully operate a factory which depends on sharks alone we are coming to see that a combination of other marine products with sharks, when properly handled in an up-to-date plant, may be considered as one of the richest "strikes" in the only inexhaustible mine—the sea.

We have been hating sharks on general principles for centuries, and in some ways they have deserved it; but now it is high time that they should pay up. There are no more interesting animals in the world, and the ways and means of turning them into cash constitute one of the most fascinating of our modern industries.

THE HIGH ATMOSPHERE OF THE EARTH

By E. O. HULBURT

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THE earth on which we live has recently been called a "seventh of a second earth," by Professor Kennelly, of Harvard University, having in mind the fact that by means of wireless telegraphy one can communicate with any portion of the earth in less than a seventh of a second, for this length of time is required for the wireless waves to encircle the globe. It is true that the wireless waves have furnished a marvelous method of communication, but they have done more than this, they have by their behavior led to information about the high atmosphere of the earth, those cold and rarefied regions several hundred miles overhead. It is really quite a long story, and at the present time it seems that we are in the midst of one of the most exciting chapters with perhaps but a dim perception of what the end will be like. It may be said that the high atmosphere, which heretofore has been a rather elusive and unexplored part of our earth, has become of importance in everyday life. The wireless engineer at any rate knows that he is absolutely dependent upon it for signals which he expects to send or receive at distances greater than a few hundred miles, and that he must in the end understand as much as possible about it for the development of his craft.

For a long time knowledge of the upper reaches of the atmosphere has been very fragmentary, indeed; it has depended on small groups of outlying observations together with much theory and speculation. The pressures and temperatures of the lower atmosphere have been investigated directly by means of small balloons carrying recording instruments to heights of twelve miles or so. The curves are extrapolated to greater heights, with full realization that possible errors may enter increasingly the higher one goes, so that at three hundred miles, let us say, one can have no great confidence in their correctness. The appearance of meteors, their brightness and the length of their trails furnish evidence sometimes confusing and contradictory of the pressures and temperatures of the high atmospheric gases. Certain absorption bands in the spectrum of the sun, particularly in the ultra-violet region, show that there is ozone in the atmosphere fifty or a hundred miles overhead; there is no appreciable ozone in the lower air around us. The polar light or aurora and the dim greenish light of the night sky between the stars which comes from our own atmosphere give evidence that some sort of electrical and light-producing action is present in the upper atmosphere. All these things are beyond our control; one merely observes them and makes what inferences are possible. With the advent of the wireless waves, however, there has come into existence for the first time a controllable means, and a powerful one, of plumbing the outer depths, just as sound waves are being used to search the earth beneath our feet.

We must go back to the year 1901 when Marconi, in his transatlantic signalling experiments, demonstrated for the first time that the wireless rays could bend around the bulge of the earth. Lord Rayleigh immediately raised the question as to how this could be. In answer Kennelly in this country and Heaviside in England independently suggested that there were electrons and ions in the high atmosphere which bent the wireless rays back to the earth again, so that the ray traveled over the earth

by successive reflections between the earth's surface and the electrified atmospheric layer, somewhat as it would do between two parallel sheets of metal. (It may be well to mention that electrons are small negatively charged particles of electricity; ions are electrically charged gas molecules or atoms, usually positively charged, although sometimes they are negatively charged. The electron is much lighter than the ion, weighing only about a ten thousandth as much. The charged particles, ions and electrons are spoken of as the "ionization"; an "ionized" gas is one in which there are a number of such charged particles.) In the following twenty years commercial wireless telegraphy developed rapidly and many new facts were brought out, but in spite of this wide technical extension little advance was made in an exact understanding of the propagation of the waves. The proper facts to give the clue were still lacking. These were finally brought to light in the discoveries of the remarkable behavior of the short waves, waves below fifty meters in length. These discoveries, demonstrated by the amateurs all over the world in the years around 1923, were developed systematically by the far-flung organization of the United States Navy.

The short waves were found to skip over regions near the transmitting station and to come down to earth again several hundred miles away. Around the transmitter there was thus a small zone of reception which soon yielded to a zone of silence which in turn was surrounded by a zone of reception. The widths of the zones of silence, or the "skip distances" as they are called, were measured for each wave-length (the skip distance increased as the wave-length decreased). These measurements showed unmistakably that in the high atmosphere there was an electron and ion layer which set in at about fifty miles above the earth and which increased in density with the height until at about 120 miles, in the daytime, there were about a million electrons per cubic inch. There is nothing unusual, of course, in this number of electrons, the number of air molecules at this height is ten million times as great and at the earth's surface is a hundred million millions times as great. Above 120 miles the electrons decreased in density, but beyond yielding this simple fact the wireless rays were powerless to tell more about this region of the atmosphere. Because any ray which penetrates to these levels is unable to return to the earth, it probably goes out into interplanetary space; at all events it is lost to us as far as we can tell now.

The skip regions of the short waves, although of great theoretical interest, were not the sort of thing to command the practical use of the short waves. If this were all they had to offer their commercial development would have ceased at once. They possessed, however, the ability of traversing great distances over the earth, with the result that communication by means of the short waves half way around the earth is now accomplished with astonishingly little power, a hundred watts or so, in the transmitter. With somewhat more power, several kilowatts, the short wave signals have been observed to pass three times around the earth before being weakened to indistinguishability. The reason that the short waves could easily reach distances quite inaccessible to the long waves was mainly that they passed through the high atmosphere with much less absorption of their energy than was the case for the long waves.

Since the wireless waves had not only given definite proof of the electrification of the high atmosphere, but had told within limits how many electrons there were and how high above the earth's surface the electron and ion layer was, the question as to the cause of the electrification was investigated. It was almost obvious from the start that the

ionization was due for the most part to the ultra-violet light of the sun, because practically all the wireless phenomena, such as ranges, skip distances, etc., changed in a regular manner from day to night and from summer to winter. Furthermore, it is well known that ultra-violet light of a suitable wave-length tears apart neutral molecules and atoms into negative electrons and positive ions. There was, of course, the possibility that other agencies, perhaps of radioactive nature in the earth or the sun, or of unknown origin, might have an important influence on the electrification. The matter resolved itself into dragging out all the lore of the laboratory which had a bearing on the case, such as the intensity of the sun's ultra-violet light, the electrification of gases by ultra-violet light, the diffusion of ions under the influence of the magnetic field of the earth, etc., hammering through the mathematics and calculating the ionization. Many facts necessary to an exact calculation were imperfectly known, but within this uncertainty the calculated ionization due to the ultra-violet light of the sun agreed as closely as could be expected with that given by the wireless waves. The conclusion was that the sunlight in the far ultra-violet was a necessary and sufficient cause of the ionization of the high atmosphere and that other ionizing agencies were uncalled for.

Since the calculated ionization in regions below 120 miles agreed well enough with the wireless phenomena it was possible to take up with some confidence the calculation of the ionization at greater heights than this in regions which as yet are unapproachable by direct experiments. The result came out that the electron density, which at 120 miles was a million electrons per cubic inch, decreased at 145 miles to a hundred thousand and at 170 miles to ten thousand. It seems fairly certain that the electronic densities for the greater heights are, if anything, underestimates. In these high levels where the atmosphere is very rare indeed, the pressure being a million millionth of the sea-level pressure, it was immediately evident that the electrons and ions would behave differently from those in the lower levels. For a charged particle will, if unhindered, move in the general direction of the lines of force of the magnetic field of the earth.

In the regions below about 120 miles the gas pressure is relatively high and the ions and electrons there are jostled about so frequently and so irregularly by their collisions with the gas molecules that they have no opportunity to be influenced by the earth's magnetic field. At greater heights, above 150 miles, where the gas pressure is much lower and collisions are rare, the ions and electrons move undisturbed in the direction of the magnetic field, and therefore they migrate to the magnetic poles of the earth and accumulate there. It does not take them very long to do this; their velocities are around a mile a second and they can move from the equator to the poles in two or three hours. In the polar regions the lines of magnetic force descend downward almost vertically towards the earth, and the ions and electrons are guided to lower levels. There, because of their increased concentration and the greater gas pressure, they recombine to form neutral molecules again and in some way set free their electrical energy of recombination to give the aurora light. Thus the energy of the aurora comes indirectly from the sun; the energy of that portion of the sun's ultra-violet light, which is absorbed at high levels in the sun-lit regions and causes the upper spray of the ionic layer, is transported to the polar regions and reappears (or a portion of it does) as the aurora. The ions may be regarded as being vaporized in the high atmosphere and distilled along the lines of magnetic force to the poles where they condense to neutral molecules again and yield up their energy of formation as

aurora light. Because of winds in the high atmosphere of the earth and of variations in the sun's radiation due to sun-spots, etc., the ion layer is probably not uniform but is a thing of shreds and patches. Upon drifting to the poles the patches lengthen into streaks and being touched into luminosity form the auroral streamers.

The total energy in the aurora light showered down to the earth during a strong display of northern lights has been shown to be at the rate of one hundred thousand horsepower; just about this amount of energy is available in the upper layers of the ionization. This is really seen to be a small amount of energy when it is remembered that the total energy received from the full moon all over the earth is at the rate of a hundred million horsepower, and from the sun is a million times this. All in all this theory of the origin of the aurora is in keeping with present-day knowledge; it can, however, hardly be said to be completely established as yet. It suggests, and must wait for the results of, many laboratory experiments on the electrical and light-producing effects in the atmospheric gases at low pressures. The aurora itself should be surveyed with the spectroscope under a large variety of conditions. Its energy should be measured, and in many ways it should be subjected to closer scrutiny than has been done up to this time. The spectrum of the south pole aurora has never been taken at all, although to be sure there is no evident reason why it should differ from that of the north pole.

To return to the ionized layer in the polar regions—because of the contour of the magnetic lines of force the ion and electron cloud would be expected to form a sort of large-stemmed mushroom over the magnetic poles, the stem of course not actually reaching down to the earth's surface but beginning fifty miles or so above the surface. The stem will perhaps be several hundred miles in diameter. Wireless waves striking the sides of this stem might be reflected back on their course and certain experiments of the Navy indicate that this may happen. The experiments consisted in transmitting short pulses of wireless waves and measuring the time for the echoes to return from the north. The time interval gave a distance about equal to the distance to the polar electrified mushroom. One can not be sure yet that these experiments have demonstrated conclusively the existence of the ionic mushroom, for the echoes may possibly have come from inequalities of the land or the waves of the sea. (From the rather easy way in which this is written one should not suppose that idle speculations are being tossed about. Every phrase has withstood severe criticism, and practically every statement has mathematical and experimental justification). The final answer can only come from continued experiment, particularly at or near the magnetic poles of the earth. With transmitters and receivers of wireless signals in these regions programs of experiments similar to those already carried out in more temperate latitudes would certainly yield information of the greatest importance and might furnish the key to the exact interrelation of wireless telegraphy, the aurora, the ozone, the magnetic storms and other phenomena.

It is interesting to look back upon these developments, which have been followed quite blindly with no notion where they were leading. One wonders what their future will be. We see now that they all point to the magnetic, and possibly the geographic, poles as being the regions where the most interesting things may happen and where experiments might be expected to yield the most fruitful results. In conclusion, it is hardly necessary to mention that the high atmosphere is not the only field of inquiry which may look for wide extension from polar investigations.

INFLUENCE OF CRYSTAL STRUCTURE ON ELECTRON EMISSION FROM METALS

By Professor H. E. FARNSWORTH
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WHEN electrons are shot against a metal target in an inclosure from which the air has been removed as completely as possible, it is found that some of these incident electrons (which will hereafter be called primary for convenience) are turned back from the target without loss of energy, that is, the direction of their motion has merely been changed without changing their speed. It is customary to refer to these electrons as reflected electrons. Others of these primary electrons make collisions with electrons in the metal, giving up energy to the electrons that are hit which, in many cases, is sufficient to completely remove these electrons from the same surface of the metal which is struck.

This discussion applies to a piece of metal of sufficient thickness so that no electrons are able to pass through it. All those electrons, including the reflected ones, which escape from the metal (hereafter to be referred to as secondary electrons) do so from the surface of the metal which is struck by the primary electrons. In order that an electron may escape from a metal surface it must have sufficient energy to overcome the attractive force which tends to hold the electron in the metal.

The electrons which are knocked out of the metal have speeds much less than those of the primary electrons. This difference in speeds is a criterion for differentiating between the reflected electrons and those which are knocked out of the metal. It is true that there is a certain ambiguity, inasmuch as some of the primary electrons which lose energy by collision may still retain sufficient energy to escape from the metal with a lower speed than they originally had. Hence, the single fact that electrons leave the metal surface with speeds much lower than those of the primary electrons would not enable one to decide whether electrons are actually removed from the metal or whether these low speed electrons are merely original primary electrons which have given up some of their energy on collision. There is, however, definite proof that electrons are actually knocked out of the metal, since for certain primary electron speeds, such as produced by a battery of a few hundred volts, more electrons have been found to leave the metal surface than strike it. This leaves no uncertainty for the primary speeds at which this occurs.

That electrons are also knocked out of the metal for a considerable range of lower primary speeds appears certain because of the manner in which the speeds of the secondary electrons are distributed. As previously mentioned, there is a group of reflected electrons leaving the surface which has lost no energy. There is also a general distribution of electron speeds extending over the region below the primary speed, which is undoubtedly due to electrons that have lost various amounts of energy on collision. In addition, there is a group of low speed electrons which increases in size as the relative number of electrons leaving the surface increases. It is this group which consists of the electrons that have actually been knocked out of the metal.

The question as to the minimum incident speed which is required to remove an electron under given conditions, although of great importance, is not so easily answered. However, it appears

that a minimum speed is required, for, unless the incident speed is greater than a certain value, no electrons with speeds appreciably less than that of the primary electrons are found to leave the metal. We, therefore, conclude that under these conditions no electrons are knocked out of the metal, even though some of the primary electrons fail to return. The minimum incident speed for which low speed electrons begin to leave the surface ought then to be that required for the removal of electrons from the metal. Unfortunately the incident speed at which this occurs is not sharply defined, so that an accurate determination of the value is impossible.

Experiment shows that the secondary electron characteristics vary greatly with the conditions under which they are obtained. All metals ordinarily have large quantities of gas adhering to their surfaces and distributed throughout their volumes between the metal atoms. A large part of the gas may be removed by prolonged heating of the metal in a vacuum at temperatures near the melting point of the metal. This removal of gas changes the secondary electron characteristics, but after heating the metal for some hours in a vacuum a condition is reached such that further heating produces no perceptible change in the results obtained.

In experiments of this sort, the source of electrons is usually a heated filament similar to that used in radio tubes. The electrons are accelerated by means of a battery to a diaphragm with a hole in it. Some of the electrons pass through the hole, thus forming a sharply defined electron beam of uniform speed. The speed of the electrons may be varied by changing the size of the battery. The target to be studied is placed in the path of this electron beam. By surrounding the target with a metallic spherical shell, the electrons which come off the target may be caught and measured with a sensitive galvanometer. By applying various electrical potentials to the collecting sphere and measuring the corresponding electron currents, one obtains a measure of the relative number of the secondary electrons which have various speeds. The whole arrangement, with the exception of the galvanometer, is enclosed in a glass tube from which the air has been as completely removed as possible.

Any one not familiar with this particular field of investigation may well ask what is to be gained from a knowledge of the characteristics described thus far. It has appeared for some time, to those competent to judge, that these characteristics when free from the effects of gas are distinctive of the atoms of the metal in question. The relation between the number of electrons leaving the metal and the speed of the primary electrons changes suddenly at certain critical speeds. This fact has been taken to signify that the atoms respond, when struck with electrons of these critical speeds, in a manner such as to effect an alteration in the number of electrons leaving the metal, and that this response is a characteristic of the external structure of the atom itself. If this view is correct, a determination of these critical speeds would then furnish information regarding the external structure of the atoms of the metal. This information would pertain only to the exterior regions of the atom since the present discussion is confined to relatively low speed electrons which are unable to appreciably penetrate the interior of the atom. These are relatively low speed electrons when viewed in the perspective of electron speeds easily attainable, although the very low speed which is acquired by an electron falling through a potential difference of only one volt is approximately 370 miles per second.

The data which have been obtained up to the present time by different observers are largely discordant. A part of the disagreement appears to be the result of different amounts of gas present in the

metal in the different experiments, but recent results of the writer[1] show that, in addition to gas, there is another factor of a very fundamental nature which has an enormous influence on the characteristics, at least for the lower electron speeds. This other factor is the arrangement of the atoms at the surface of the metal with respect to one another. Although each metal has a definite crystal structure, in an ordinary sample the crystals are broken into very small pieces and oriented at random. If the metal is heated near the melting point for a considerable length of time some of these crystals grow larger at the expense of their neighbors. After copper has been heated at red heat for an hour or two in a vacuum, the single crystals at the surface are large enough to be easily visible with the naked eye. Thus when a metal is heated in a vacuum, not only is a considerable amount of gas removed, but the arrangement of the atoms with respect to each other changes.

Various results by the writer had indicated that the secondary electron current is in some way dependent upon the arrangement of the surface atoms, but definite proof of this was recently established when the secondary electron current as a function of primary speed was obtained for a target cut from a single crystal of copper. This relation was found to be distinctly different from that for an ordinary or polycrystalline sample of copper. Evidence of the influence of structure was also obtained from the characteristics of a target of phosphor bronze which contained more than 95 per cent. copper. If the results are distinctive of the atoms independent of their arrangement, then the results for a target containing over 95 per cent. copper would not be expected to differ appreciably from those for pure copper. If, however, the arrangement of the atoms is a determining factor, the presence of a small percentage of other atoms might be sufficient to produce considerable changes. The results obtained for phosphor bronze were distinctly different from those for copper in the ordinary, or in the crystalline form, showing that the modified atomic arrangement must be responsible for the change.

These experiments were not extended to primary speeds greater than that corresponding to about forty volts, so that it is impossible to give the maximum speed to which this applies. It appears probable, however, that this effect is confined to relatively low speeds.

The effect of atomic arrangement on the secondary electron current is not necessarily at variance with the view that the secondary electron characteristics are distinctive of the structure of the atoms. It may simply mean that the outer structure of an atom, which is the only part here effective because of the low speeds of the primary electrons, is dependent upon the arrangement of the neighboring atoms. That is, the outer energy levels of any one atom may be modified as a result of the close proximity of neighboring atoms and thus be a function of the environment of the atom. Should this prove to be the correct interpretation, it follows that all other phenomena which are a function of the outer energy levels of the atom must also be affected by atomic arrangement. It appears that some of the discordant results in the field of soft X-rays may be accounted for in this way. This remains for future work to decide.

The experiments described here, however, have definitely proved that the arrangement of the atoms in a metal is a determining factor for certain phenomena which were formerly attributed to the individual atoms independent of their environment.

[1] *Phys. Rev.*, Mar., 1928.

MATHEMATICS IN BIOLOGY

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WHAT is mathematics? And what right has mathematics to obtrude itself upon the attention of biologists?

Since mathematics is a very old science, inextricably bound up in its historical development with logic and philosophy on the one hand and with astronomy on the other, it is perhaps impossible to give a concise definition which would satisfy the workers in all its fields, theoretical and applied. It is easier and more pertinent to our present purpose to indicate some of the characteristics of mathematics which make it an essential factor in the more advanced stages of the development of all other sciences. This may serve as a preliminary to an outline of the claims of mathematics to the attention of biologists, based on *a priori* considerations, on service in other natural sciences and on the contribution which it has already made to the advancement of biology.

I. THE FUNDAMENTAL CHARACTERISTICS OF MATHEMATICS AS RELATED TO THE PHYSICAL AND BIOLOGICAL SCIENCES

It is one of the characteristics of mathematics that, starting with certain axioms, postulates or assumptions, it shows the way in which conclusions may be deduced from these premises. The mathematician does not necessarily claim absolute certainty for the physical validity of his conclusions, but he believes profoundly that it is possible to find groups of axioms—sets of a few propositions each—such that the propositions of each set are compatible and that the propositions of each set imply other propositions, which latter can be deduced from the former with certainty. The assumptions of pure mathematics need have no physical interpretations. They may indeed contradict any of our theories. They must not, however, contradict each other. Thus it is the business of the pure mathematician to discover systems of self-consistent and coherent propositions.

Mathematics is an exact and final science only in the sense that with the postulates definitely given the conclusion admits of no doubt. Thus the pure mathematician concerns himself not with the solution of particular problems in the natural sciences but with the principles which underlie the solution of problems in general.

In the natural sciences, as contrasted with mathematics, the things which are given are measurements of natural phenomena rather than axioms or postulates. The scientist wishes to derive from these observational data generalizations which we call natural laws. It seems both reasonable and desirable that he should endeavor to employ in this task the rigorous self-consistent systems of reasoning developed by the mathematician.

The student of natural science need not necessarily concern himself with the criteria by which the mathematician assures himself of the validity of his formulae. He desires merely to be fully convinced of the usefulness of such formulae in the solution of the problems with which he himself has to deal. He should be sufficiently conversant with the fundamental assumptions underlying the equations which he proposes to use in his investigations, not to make the error of applying them in problems presenting wholly different sets of conditions from those for which they were developed.

The biologist in common with the student of the other natural sciences starts with a series of direct observations of phenomena. From these he wishes to derive a generalization, a theory or a law which shall express the results of his experience in concise and mentally comprehensible terms. A theory deduced from a given set of observational data may be erroneous because the measurements were made under unsuitable conditions, by inadequate methods, or because they are for some other reason unsuited for use as a basis of generalization. If the theories based on two or more sets of observations are inconsistent, the experimentalist refines the conditions under which his observations are made, increases the precision and number of his measurements and reformulates his theories until he finds one which is in accord with the widest possible range of experience and which appeals to him as a reasonable description of the facts of nature. Thus, were the mathematician to criticise the worker in the natural sciences, he would not require him to give up observation and experimentation but would only demand that the conclusions drawn from observation and measurement be logical conclusions.

II. The Claims of Mathematics to the Attention of Biologists

The claim of pure mathematics to the attention of scholarly mankind is like that of art, in that it is grounded in the innate human love of beautiful things and in the innate human joy in originating them. It is creative. Its previous triumphs of achievement fill us with satisfying wonder; its pursuit is akin to that of the exploration of a great mountain system in the course of which the vantage of each peak scaled opens to view the prospect of higher serried peaks and vaster plateaus beyond.

The pursuit of pure mathematics in our day by the few who have the ability and the training is not to be justified by the immediate applicability of its results in the other sciences. Its present existence is justified by centuries of persistent appeal to human interest. In no generation in which we would deem life worth while has such interest in mathematics been lacking. Thus its claim to the attention of the scholar has been tested by a rigorous natural selection. The survival of the science is sufficient evidence for its value as a source of gratification to the active human mind. Furthermore, the process of natural selection has not merely shown the fitness of pure mathematics as such for survival. It has been active within mathematics itself. All that has not been found to be sound and consistent has been ruthlessly eliminated. Thus all that has long remained may properly appeal to workers in the other sciences as worth their consideration with reference to its possible value in their own special field.

But here we are not concerned with the justification of pure mathematics, but with an appeal for the wider use of mathematics by biologists as a means to the development of their own special field of creative scholarship.

Let us consider in outline the claims which mathematics has to the attention of the working biologist.

The first two may be stated in very general terms. They will, however, be developed in the discussion of special claims which is to follow.

The most universal service of mathematics to the natural sciences is the affording of an exact and easily workable symbolism for the expression of ideas. The progress of science depends very largely upon the facility with which facts may be recorded and relationships between them considered. In their bearing upon this requirement of

the natural sciences it is important to note that an essential characteristic of mathematical methods is that they economize thought. The notation of the mathematician affords the maximum precision, simplicity and conciseness. The worker in natural science finds in mathematical literature a highly perfected symbolism which he may use without developing one of his own.

But while a convenient notation is the most general contribution of mathematics to the natural sciences, it is neither the only nor the most important one. In the natural sciences it is essential that accurate observations and exact measurements be interpreted by sound processes of reasoning. It seems logical to assume that the biologist may profit by the centuries of experience of the mathematician in the drawing of inevitable conclusions.

These claims are so general that we may properly turn to those based on the specific accomplishments of mathematics in the physical sciences and in biology itself in substantiation of our argument for its wider application in biological research.

(1) The Claim of Service in Other Physical Sciences

The record of service of mathematics in the physical sciences is an outstanding claim to the attention of biologists.

In the past, mathematics has been an integral part of the sciences which we are accustomed to regard as the more highly developed—of all that is physical as distinguished from biological in the growth of our civilization. The most determined critic of the application of the mathematical method in biology dares not contemplate the consequences of a Maxwellian demon snatching from our scientific literature and from the minds of our chemists, physicists, engineers and economists the mathematical formulae which underlie the routine of our daily life. In a few weeks long-distance communications would cease, the vehicles of transportation would be motionless, factories would close, and urban population would face starvation. As Professor A. Voss said in 1908, our entire present civilization, as far as it depends upon the intellectual penetration and utilization of nature, has its real foundation in the mathematical sciences.

If reasoning by analogy is ever justified, experience in the physical sciences would certainly seem to afford sufficient evidence of the necessity for the extensive introduction of this powerful tool of research into the biological sciences.

The argument that biologists should emulate the workers in the physical sciences is strengthened by the fact that biological phenomena are the most nearly infinitely complex of all natural phenomena. This is necessarily true because the internal structure and functioning of the organism and the effective environmental conditions under which it must live and reproduce comprehend a material fraction of the physical and chemical complexities of the universe. Before the more complicated biological phenomena can be grasped in any but the most circumscribed and superficial way by the human mind, they must either be analyzed and simplified by experimental control or expressed in the mentally intelligible terms of mathematical summaries or generalizations.

It may be urged that the method of dealing with large numbers of measurements is not that of the physicist or of the chemist who frequently works with minute samples under carefully controlled conditions.

The reasons for the differences in methods are two. First, the student of molecules has the advantage of working with less complex materials and under more readily controlled experimental

conditions. Second, the physicist or chemist already has his molecules or ions massed and can investigate them and draw conclusions concerning their properties from his examination of the properties of his volume of gas or solution. The biologist must begin otherwise. He must collect and determine the characteristics of each individual of a large sample in order to express the characteristics of the whole population in mathematical terms.

When biologists have had the necessary preliminary training, they will realize that, for many of the phenomena with which they have to deal, the most easily comprehensible and the most useful method of description and analysis is the mathematical.

In the past, biologists as a class have been in reality hostile to the introduction into their science of the methods which have proven their worth elsewhere. I know this to be true from long and bitter experience. Instead of being eager to place biology alongside of physics and chemistry in the ranks of the exact sciences, biologists have seemed not merely to excuse, but actually to take pride in the distinction which has been drawn between the so-called exact and so-called descriptive sciences.

While the historical attitude of the biologist is not excusable, the fault has not been entirely his. With most men mathematics is like a well—the deeper they go in the less they see out and about. Mathematics may quite properly be an end in itself, but in biology it is strictly a means to an end. While mathematicians have in the past been eager to serve workers in the physical sciences, and while mathematics itself owes a large debt to these sciences, mathematicians have not for the most part felt it worth while to come to the assistance of biologists. Mathematicians have often asserted the need of mathematics in the biological sciences, but the claim has too often been made in an *ex cathedra* manner by those who, while perhaps qualified to speak of things mathematical, have been relatively little fitted to discuss the needs of biology. While biologists have been entirely too slow in recognizing the needs of their science for the mathematical tools, they have shown that practical good sense which characterizes those whose minds have contact with matter by refusing to flock to the mathematicians' standard until shown by concrete examples that the mathematical method has real applicability in biology. Thus the burden of proof has largely been thrown upon a few workers of greater vision, with the inevitable result that progress in the application of mathematics in biology has been slow.

Progress has been slow, but progress there has nevertheless been.

(2) The Evolution of Biology and the Influence of Quantitative Methods

The natural sciences have had their beginnings in observation and speculation. Careful description of the observed phenomena then furnished a basis of interpretation by comparison. Experimentation, which requires not merely controlled conditions but measured consequences, followed observation and description. Finally quantitative measurement, calculation and the formulation of mathematical laws have characterized the highest stage of scientific development.

These stages in the development of the natural sciences are, to be sure, neither wholly distinct in nature nor sharply separated in time. The methods of the later stages have in some instances been anticipated by investigators who were in advance of their contemporaries. It would be unfortunate indeed if men of science did not at all times avail

themselves of whatever is best in the methods as well as in the results of those who preceded them. Notwithstanding the difficulty of delimiting the various horizons, as our geological friends might feel inclined to designate the deposits of scientific literature of these periods of differing dominant purposes, the sequence is in full accord with historical facts.

The old physicist who defined the biologist as "a man with scientific aspirations and inadequate mathematics" would find, if he looked over a fair sample of current biological literature, that not only has the space devoted to quantitative data increased enormously during the past few years, but that there is a steadily growing effort on the part of biologists to express in concise formulae the results of observation. Unfortunately biology in most of its phases still lacks the quantitative data and biologists in general want the training in mathematical analysis which is essential in exact science. Nevertheless the tendency of the times is unmistakable; the demand for quantitative work is more and more dominant in the biology of to-day.

The most forceful argument for the wider use of mathematics in biology is furnished by the service which mathematics has already rendered in the biological sciences. Let us consider this more specifically.

(3) The Two Fronts of the Advance of Mathematics into Biology

Progress in science depends upon evolution of method as well as upon the accumulation of the data of observation, experimentation and measurement. The progress which has been made in the development of biology as a quantitative science through the introduction of mathematical methods is in its present stage the resultant of various factors, which can only be understood when considered in their relation to the evolutionary history of science in general and of biology in particular.

This evolution of the natural sciences is admirably illustrated by the history of biology. Observations and speculations began with primitive man. If a desire to record what has been seen formed a part of the motives of those who bruised crude figures on the walls of caves, descriptions began with or before the period of written language. Some attempts at classification were made at a very early period in man's cultural development, but we are accustomed to think of the great era of description and classification as initiated in their modern form by the work of Linnaeus. This period was also one of detailed geographic exploration. Breadth of exploration doubtless tended to stimulate intensity of interest in description and classification. The activities of these decades resulted in the storing of great museums with carefully preserved and minutely described specimens of plants and animals, in the publication of elegant icones which are among the masterpieces of artistic bookmaking, comprehensive monographs of every large genus, encyclopedic summaries of phyla and kingdoms, and floras and faunas to the end of long vistas of library shelves.

Simultaneously with the latter decades of the period of description and classification of organisms, both living and fossil, began the development of anatomy and embryology, both macroscopic and microscopic. These latter were indefatigably pursued by an army of workers whose investigations were so comprehensive that the younger and more restless spirits began to fear that there would be no worlds left for them to conquer.

With such a wealth of descriptive materials at their disposal, it was inevitable that serious attempts at inter-

pretation should be made. Speculation as to the observed phenomena was largely replaced by effort at interpretation based upon comparison. "It is descriptive but not comparative," was the criticism of a volume laid before the elder Agassiz. The dominance of the comparative method over a considerable period of the more recent history of biology is attested by the presence of the word *comparative* in the titles of a number of institutions and journals.

With taxonomy, comparative anatomy and embryology, histology and cytology well outlined, biologists found themselves free to extend to other fields the methods which had heretofore been limited to physiology. Experimental morphology, experimental embryology and experimental evolution are terms which illustrate the degree to which the experimental method has dominated biological investigation during the last few years.

(a) *The Influence of Physics and Chemistry*

As soon as biology, in the course of its evolution, had passed the purely observational and descriptive stage and become an experimental science, it was natural that the attempt should be made to interpret biological phenomena in terms of the more highly developed sciences of physics and chemistry.

That many of the processes which occur in the living organism are chemical and physical in nature was necessarily admitted as soon as physiology could be called a science. The controversy between those who asserted that all biological phenomena are physical and chemical and those who maintained that living matter is in some essential way different from non-living matter has only served to stimulate investigations having to do with the physics and the chemistry of life processes.

The development of the field of physical and chemical physiology has been due not merely to its great theoretical interest but to its enormous practical importance in agriculture, in the industries and in medicine. At present biophysics and biochemistry have attained the rank of independent sciences, commanding facilities and personnel greater than that available for the whole of biology, with the exception of taxonomy, a few years ago.

The intimate contact with the more precise sciences of physics and chemistry which has resulted from the rapid development of experimentation in biology during the past few years has done much to raise the standard of biological research.

Physics and chemistry are not merely sciences characterized by measurement rather than observation. They are sciences in which it has long been recognized that progress depends upon the exactness of the control of the conditions of experimentation, the precision of the measurements, and the adequacy of the mathematical description and analysis of the measurements which have been made. Here we have one of the two great lines of advance of the mathematical method into the biological sciences. Physics and chemistry are quantitative and, to a high degree, mathematical sciences. Biologists, if they will pursue their science along the lines of physics and chemistry, must take over the mathematical methods of expression and analysis characteristic of these sciences. There can be no reasonable doubt that in the future physics and chemistry will continue to influence biology, and even more profoundly than in the past. As the association of these sciences becomes more intimate, and as the biologist becomes essentially a chemist or a physicist working with living organisms, the mathematical mode of description and analysis which have been so fruitful in physics and chemistry will become increasingly significant in biology.

(b) *The Rise of Biometry*

The penetration of the mathematical leaven into the biological lump through the medium of physics and chemistry has been so gradual and so little associated with the names of any individual workers that it has taken place without biologists as a class being acutely aware of the profound change in their science. The case is quite different with the second great line of advance of the mathematical methods into biology. This is directly traceable to the development, initiated by Francis Galton and strenuously carried forward by Karl Pearson, of mathematical formulae suitable for the analysis of the highly variable data of biological observation and measurement and to the application of these methods to a wide range of biological and sociological problems by the biometric school.

While the biometric methods were developed primarily for the study of phenomena which are so complex that they can not be grasped by the unaided human mind or which can not be readily subjected to experimental control, they are now being advantageously applied to the results of experimentation. Biologists will doubtless some day realize that experimental results must receive mathematical treatment for their full interpretation.

For the present, there are many who stubbornly refuse to see.

We are sometimes told that the biometric constants are merely a useful means of expressing results. The idleness of such an assertion will be apparent from two simple illustrations.

All mankind has had the opportunity of observing the statures and other physical characteristics of husbands and wives. Yet it remained for Pearson and his group to show that there is a high degree of assortative mating in man. Why was this not perceived if the correlation coefficient only serves to express what we may learn otherwise?

If the suggestion be made that those individuals who observed human husbands and wives were for the most part scientifically untrained, the reply is evident. Students by the thousands in the biological laboratories of the world have observed conjugation in Paramecium, but it required the biometric investigation by Pearl, working under the influence of Pearson, to show that in the union there is a high degree of similarity in the size of the conjugants. Even after the relationship was clearly demonstrated biometrically, its validity was denied by at least two eminent zoologists. If biometric methods are a useful means of expressing but not of obtaining results, why did not zoologists long ago note the assortative conjugation demonstrated by Pearl, and arrive at the explanations afforded by the masterly studies in the same field by Jennings?

The answer is obvious in both cases. Unaided observation was incapable of dealing with the problems. They required for their solution the application of mathematical methods of analysis to series of measurements.

These are by no means unique or exceptional cases. Instances of the failure of biologists to observe important relationships, even with the materials or the data before their eyes, could easily be multiplied. Examples of the misinterpretation of materials or data equally open to observation could be readily adduced. The mental limitations implied is not peculiar to biologists. The inability to grasp the more complicated natural phenomena without symbolism is an inherent limitation of the human mind, fully recognized by psychologists. That a man should be unable to reason about highly complicated phenomena without the use of mathematical formulae is no more remarkable than that he should be unable to see chromosomes without the microscope.

Another criticism frequently heard is that the statistical methods can only

locate problems—never solve them. The real solution, we are told, must in the end be biological, psychological, sociological, as the case may be. If this be true, it is the more important that the biologist, psychologist and sociologist be themselves capable of using the mathematical methods, or at least of cooperating intelligently with those who can. But is the criticism really valid? The same stricture is equally applicable to all methods of research. After a group of phenomena have been described and analyzed as well as they can be by any means, other problems remain to be attacked by new refinements of method or of analysis.

The assertion is often made that the final results must depend upon the original measurements and not upon their mathematical treatment. A full discussion of this criticism would lead into several complexities, but it is sufficient to answer by a very simple illustration. The possibility of securing accuracy beyond the power of observation, or at least beyond the degree of refinement of the measurements adopted, may be easily tested by measuring a series of objects twice, once roughly and once with great accuracy. The statistical constants of these two series of measurements may then be calculated and compared. Unless there has been a consistent bias or personal equation on the part of the observer which tends to make all his measurements too high or too low, there will be a remarkably close agreement between the results of the constants calculated from the gross and from the refined series of measurements.

Finally one of the most common criticisms of the biometric methods is that they are complex and difficult to use. We have been told seriously by biologists that they expect to adopt the biometric methods when they shall have been more simplified and hence made more suitable for practical use. But research does not tend to become simpler with the advance of science. Since biological phenomena are innately complex, there is no likelihood that the mathematical formulae required for their investigation will be simplified except in matters of practical technique. Criticism of the biometric methods on the ground of their difficulty is merely the glorification of the mental lassitude of the critic.

Let us turn from the answering of criticisms to things more constructive.

If science is to advance at the rate which we desire, another highly practical consideration can not be neglected. Many biological phenomena can not be subjected to experimental control. Thus while the proper study of mankind may be man, human individuals and their relatives can not be investigated in the same manner as white rats and Drosophila. While man may be the most conspicuous illustration of an organism which can not be studied in a broad way under controlled conditions, the example is not unique. In innumerable cases the statistical study of masses of data may not only properly, but must necessarily, replace controlled experimentation. I hope to show later that in such cases the experimental and the statistical method are in essence identical.

Even where refined experimentation is possible the biometric methods are particularly suited to reconnaissance work. In the search for the relationship between different variables the statistical analysis of large masses of comparatively rough data may indicate the place in which carefully controlled experiments may and should be made. Finally, after biological problems have been subjected to as close experimental control as possible, the results are generally so irregular as to make biometric analysis desirable.

Let us consider briefly, in review, the claims of the biometric methods to the attention of biologists.

First: The biometric notation makes possible the expression of the results of extensive experience in concise and mentally comprehensible terms.

This matter of the form of expression is one of far greater importance than might at first be realized. Rapidity of progress in any branch of science must depend very largely upon the facility with which the data and conclusions of a new investigation can be compared with those already on the library shelves. It is by the reoccurrence of like results that general theories are established. It is by the noting of inconsistencies and the circumstances under which they occur that indications of as yet unsuspected relationships are often seen.

There can be little doubt that the rapid advance of physics and chemistry has been due in no small degree to quantitative and standardized modes of expression.

If the physicist or chemist wants a solubility, melting point or conductivity of any substance, he has merely to turn to volumes of constants to find whether it has been determined, and if constants are available, whether the recorded results accord with his own. An investigator has been able to draw upon a common fund of knowledge to a greater extent and with greater ease than in biology. Thus synthetic work has been facilitated.

In its bearing on the problem of the simplification of scientific literature, consider for a moment the state in which biology would have been to-day had it not been for the Linnaean notation by which species may be designated by a simple binomial instead of by a cumbersome description whenever mentioned. The value of this relatively succinct notation becomes especially apparent when we contemplate the vast harm which has been done to scientific research through the unwillingness or inability of taxonomists to maintain uniformity of nomenclature. Then in view of what has been accomplished by this relatively simple expedient, imagine the rapidity of advance which will be possible when a quantitative mode of expression permits the results of many fields of biological research to be summarized in annual volumes of standard constants. I, personally, am inclined to look upon the publication of Donaldson's volume on the rat, in which the experience of a whole institution of workers is summarized in quantitative terms, as a real milestone in the progress of biology.

Second: The biometric formulae provide a system of probable errors which safeguards the worker in the formulation of his conclusions. Biometricians have referred so freely to probable errors that critics have facetiously suggested that biometry is chiefly error. But frankly and candidly, if a given set of observations are insufficient to demonstrate a relationship, is it not better that the investigator discover the fact himself rather than publish erroneous conclusions which must be corrected by subsequent research?

Third: The biometric methods furnish not merely a system of mentally comprehensible constants and concise equations, suitable for the description of complex phenomena, and a series of probable errors which safeguards the worker in drawing conclusions concerning these phenomena, but they make possible the investigation of relationships so intricate and so delicate that they are quite beyond the scope of unaided observation. Here the biometric methods have a potentiality for service analogous to that of the equipment of the modern observatory, which is capable of dealing with stellar phenomena that were beyond imagination a century ago or to that of modern microscopic equipment and technique which have given rise to whole sciences of microcosms which were beyond the ken of Linnaeus. To argue

that it is unnecessary to push on into the investigation of these more recondite relationships is as contrary to the spirit of science, as reactionary, as to argue that it were better to have stopped with Galileo instead of advancing to the refinements of modern astronomy through the development of instruments and mathematical theory.

Fourth: For many classes of problems the biometric formulae applied to large masses of data furnish the closest possible approximation to the experimental method of investigation.

The experimental method, as ideally applied, consists essentially in the simplification of conditions by rendering constant all but one. This one factor is then varied and its influence upon the organism is noted. In certain phases of statistical analysis an essentially identical method is followed, when we determine what is called the partial correlation between two variables for constant values of one, two or more other variables.

For example, the basal metabolism of tall men is on the average greater than that of those of less stature. Heavy men also show a higher daily gaseous exchange than light ones. But taller men are on the average heavier men, and it seems quite possible that the larger basal food requirements of taller men is merely the resultant of the relationship between stature and body weight on the one hand and between weight and metabolism on the other. The biometrician solves such a problem statistically by determining the partial correlation between stature and metabolism for constant weight, *i.e.*, with the influence of body weight eliminated. The experimentalist would have to attack the problem in exactly the same manner.

Illustrations might be given by the score of the analytical treatment of statistical data which gives results of essentially the same nature as those attained by the experimental method, often in cases in which strictly experimental technique can not be readily applied.

Fifth: The biometric formulae furnish the best means as yet available for predicting the value of one variable from another, or from a series of others. This is due to the fact that it is possible to pass at once from measures of interdependence in terms of the universally comparable scale of correlation to regression equations showing the rate of change in terms of the actual working scale of any variable associated with another, or others, whose values are known.

The great theoretical importance of this feature of the biometric methods will be realized when we remember that the test for the validity of a theory is its capacity for predicting the unknown.

The foregoing treatment in outline may have been disappointing to those who have expected argument by illustration of specific accomplishment. The method has been followed because the biological contributions which have already been made through the use of the biometric methods are now so large that no one man, even with unlimited space, can be expected to summarize them. This is true, notwithstanding the fact that the number of workers who have persistently stood by the biometric guns during the long and discouraging years of general biological indifference can be counted on the fingers without using all the digits of the hands.

III. The More General Service of Mathematics in Biology

It would be unfortunate to bring this paper to a close without emphasizing both certain limitations and certain wider services of mathematics to biology.

The biological universe is all but infinitely complex. It is not conceivable that all biological phenomena will be

treated by mathematical methods. All that is necessary, however, is that the mathematical methods of research be so developed that they may be applicable to any biological problem.

Nor must there be misunderstanding concerning the desirability of an unbroken front comprising all the methods of research in the attack on the complex problems of the biological universe. In biology evolution of scientific method has been of surpassing rapidity. Description was deserted when comparison became the order of the day. The mines of comparative morphology were in part abandoned when the cry was raised that experimentation was uncovering solid nuggets. The problems of biology are so numerous and so varied that no method of research can be permanently discarded. Observation can never fail to be the cornerstone of biology. The task of classification is only partly completed, even by those methods which were in use at the time when it was the major interest of naturalists. Taxonomy must profit by and ultimately incorporate all the pertinent facts unearthed by the newer methods of research. Comparison can never fail to yield results of importance. But all these methods may now be made more refined and exact by the introduction of mathematics applied to the description and analysis of quantitative data.

In closing, I would like to return to the broader subject of mathematics in biology and to emphasize two points.

My first point is in the nature of a prophecy.

In the future mathematics will have an increasing influence in determining the direction of research.

This is not due solely to the fact that the biometric formulae facilitate the solution of many problems but to the fact that after a certain stage in science is reached, calculation is to some degree capable of anticipating the results of experimentation. The value of the mathematician's prediction is well known to the physicist, chemist and astronomer. As yet little progress in this direction has been made in biology, but I am glad to go on record as predicting that before many years have passed experimentation will be to a considerable extent guided by preliminary calculation.

My second point has to deal with a very different matter.

Elegance or form has always made a powerful appeal to the mathematician. As the biologist is forced by the inevitable progress of his science to occupy himself more and more with mathematical literature, its logic, terseness and elegance of expression must have an influence upon his own standards of presentation.

Summarizing in a few sentences we may note that mathematics is driving into biology on two wide fronts.

On the one, physics and chemistry are by virtue of their influence upon biological research forcing biologists to take over the mathematics which is an indispensable part of these sciences. On the other, biometry is grappling with problems which are not readily amenable to experimental treatment.

The possible contributions of mathematics to biological science are too varied to be succinctly summarized. We must, however, record our entire disagreement with the dictum that mathematics is only a mill from which no more comes out than was originally put in. What is put in is raw data, the significance of which is obscured by all the perplexing irregularities due to morphological and physiological variation, to errors of random sampling and to errors of measurement. What comes out is a series of mathematical constants and equations, epitomizing in mentally intelligible form the whole discordant mass of irregularities and smoothing them in a manner to bring out the underlying

laws. To assert that the value of a biometric research is determined by the raw biological data is not altogether unlike measuring the value of a Titian by the grams of paint required to cover the canvas.

It has been the rare good fortune of Quetelet, Galton and Pearson to initiate one of the great lines of advance in biology. These men will one day receive from biologists recognition as free and generous as their great service merits. As for the rest of that little handful of workers who have made up the biometric school, it has been the satisfaction of a few never to have stepped back from the guns during the long and discouraging years of biological indifference and opposition.

The ultimate recognition of mathematical biology is merely a part of that inevitable and irreversible evolutionary process by which biology is to take its place in the ranks of the exact sciences.

AMERICAN OVER-SEAS CARRYING TRADE

By Professor EZRA BOWEN
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MORE than half the ships entering ports of the United States in 1790 were American. Only England offered serious competition.[1] Just before the Civil War, the tonnage of the United States, including ships engaged in domestic commerce, was not far from one third the total tonnage of the world; Great Britain accounted for another third; the tonnage of all other countries, taken together, scarcely surpassed the American. The merchant fleets of the United States exceeded by half the number necessary for the carriage of exports and imports.[2] A poor, new country, during the first seventy years of its life, held a leading position among seafaring nations. But a startling decline occurred in the next half century. Just before the World War, the overseas shipping of the United States had shrunk to a scant one million tons—compared with England's eighteen million tons![3]

During the World War the tonnage of the United States engaged in foreign trade increased enormously. A scant million tons in 1913 became nearly two and one half million in 1917, and by 1921 the forced draught of wartime construction, continuing into the post-war years, had produced a total tonnage engaged in foreign trade of more than eleven million.[4] But this great expansion was purely an artificial growth produced at great expense. At Hog Island, the largest of the war plants, the cost of construction varied from month to month between $125 a ton and $200 a ton for the hull and a similar amount for the machinery. At the same time ships were being built on the River Clyde at a cost which amounted to one half or one third of the American figures. After 1920 this war-tonnage went rapidly out of use, and, in spite of the activities of the U. S. Shipping Board, the tonnage of ships built and documented in the United States appears to have returned to prewar levels.[5]

The point of greatest interest, however, in this brief recital of the history of the foreign-going[6] merchant marine of the United States is the spectacular success achieved in the years which lie between the founding of the nation and the Civil War and the even more striking decline in per capita overseas tonnage between the Civil War and the Great War.

What causes lie behind a nation's gaining a leading position in the carrying trade, and then suffering a complete collapse—all within little more than a century? What do the historians say? The almost rank growth of the early American overseas carrying trade is explained in terms of ready cargoes, excellent harbors and abundant shipbuilding materials. These are strong and self-evident points of argument, but their strength melts instantly when one recalls that they lost entirely their effectiveness after the sixties of the past century. If harbors, cargoes and shipbuilding materials include all of the causes of the early rise of American shipping, it is necessary in explaining its subsequent decline to show that one or more of those factors disappeared—a stiff task. Good harbors remained, and

[1] Johnson, Emory R., (and others) "History of Domestic and Foreign Commerce of the United States," Vol. ii, p. 11.

[2] Day, Clive, "History of Commerce," 1922, p. 526.

[3] The Statesman's Year-Book. 1926.

[4] Lloyd's Register of Shipping, 1925.

[5] "Statistical Abstract of the United States," 1926.

[6] The lake, river and coastwise trade is reserved by law to ships of American registry—it is a domestic monopoly.

few would agree that cargoes were less abundant. It does appear, however, that radical changes in ship construction came with the decline in tonnage which it is so hard to explain. Ships of metal began slowly to take the place of wooden vessels. Steam instead of sails became the propelling force. But the United States was as rich in coal and steel and engineering skill as ever she was in wood or in the art of sailmakers. High wages drove American ships from the ocean.[7] True enough, but what made wages high?[8] Other explanations are offered for the sharp decline in foreign-going tonnage following the Civil War: Steel and steam becoming established in shipping while America was in the throes of civil war—or recovering from the effect—England took advantage of her diversion and won a lead which it was impossible for Americans to overcome.[9] This argument loses force, however, when one recalls that Japan's merchant marine was developed almost entirely in the past fifty years—establishing clearly that a time handicap, however great, is not fatal when conditions fundamental to the growth of a merchant marine are present. A collateral explanation of the almost total disappearance of the American flag from the high seas, after the Civil War, is that privateers flying the Confederate flag destroyed so great a proportion of the American tonnage that her citizens could not make good the loss.[10] But this explanation seems to assume that the ratio of loss to total was greater than the proportion of British ships which fell victims to German submarines and cruisers during the World War; for that loss was completely recovered, and no one pretends that it had any permanent effect upon the prestige of British shipping. The war loss of Great Britain was 7,379,986 tons—more than the entire merchant fleets of any *two* other nations.[11] No; we must look elsewhere for an adequate explanation of both the rise and fall of the American overseas shipping business—and a criterion for judging its future trend.

Most commonplace things are inconspicuous. A well-known trick of the mind relegates them to oblivion. In this way it has been generally overlooked that man is not a marine animal. Man is content to remain ashore so long as he can find a living there. Nations do not develop an overseas carrying trade until they are forced to. Flying fish learned flying to save their lives. Bats developed wings and took to the air by necessity. Whales, which the biologist tells us are mammals and by nature land animals, went down to the sea in droves only under compulsion. Men went down to the sea in ships only when they could not make a living upon dry land. We offer as a hypothesis of the development of an overseas carrying trade the proposition that nations do not develop merchant fleets until other opportunities for livelihood have become overcrowded. Let us see how far it goes toward explaining the rise and decline of the merchant marine of the United States.

In its early years the United States was a poor, slight nation.[12] Thirteen miserably endowed agricultural states, strung loosely along fifteen hundred miles of coast line, the western part of many of them was little better than wilderness.[13] With land transportation what it was in that day, these states appeared to be hopelessly hemmed in between the sea and the great Appalachian

[7] Oberholtzer, E. P., "A History of the United States since the Civil War," p. 214.

[8] It was mainly the opening of the West that ran up wages—and furnishes the pivot (see below) of our theory of the decline of American shipping. Both are the result of one change, the opening of the vast new economic opportunities.

[9] *Cf.* Oberholtzer, E. P., "A History of the United States since the Civil War," p. 214, *ff.*

[10] Day, Clive, "A History of Commerce," p. 558.

[11] Fayle, C. E., "The War and the Shipping Industry," p. 418.

[12] "Cambridge Modern History," Vol. 7, The United States, pp. 305–688.

[13] McMaster, John Bach, "A History of the People of the United States," Vol. 1, p. 3.

barrier. The center of population was twenty-three miles *east* of the city of Baltimore.[14] As late as 1800 there were only six "cities" with a population of more than eight thousand inhabitants.[15] In contrast with the present, it was estimated that nine tenths of the people were farmers. Even in New England, where such meager industries as existed were centered, only one eighth of the people were employed in manufacture, trade and pursuits other than agriculture.[16] Even agriculture was badly carried out and the yield was often slight. Washington wrote to an English agriculturist: "The English farmer must have a very indifferent opinion of our American soil when he hears that an acre of it produces no more than eight to ten bushels of wheat; but he must not forget that in our country where land is cheap and labor is dear, the people prefer cultivating much to cultivating well." Clive Day says of manufacturers in the United States at this time that only one—the manufacture of rum—was strong enough to produce a considerable surplus for sale outside of the country, and that all manufactories were of a simple character requiring no great technical skill or elaborate machinery.[17] Roads, which furnished the only means of communication and transportation by land, were the dirt roads of the colonial period, thick with dust in summer and sloughs of mud a foot or more deep during the thaws of winter and spring.[18] Wagons were nearly everywhere a rarity. Sledges were used on the farm. Persons and products moved from point to point on horseback. There was so little intercourse between the adjoining towns of East Hampton and North Hampton, on Long Island, that each town preserved peculiarities in pronunciation down to the year 1800.[19]

During the colonial period (the effect extended well into the federal period) manufacture was further discouraged by English legislation. The exportation of manufactures was restricted; the importation of machinery was prohibited; trade even among the colonies was curbed.[20] Early mills in New England were built from smuggled plans or from the memory of some skilled Manchester immigrant—even the emigration of skilled workers was prohibited by England.[21]

One industry, however, shipbuilding, was encouraged by British legislation.[22] The colonies supplied not only their own need for ships but sold them abroad. Before the Revolution more than a third of the British tonnage, it was said, was American built.[23] In Massachusetts towns, a ship could be built of oak for $24 a ton, while in England, France or the Netherlands an oak vessel cost $50 to $60 a ton.[24] Even fir vessels, built on the Baltic, inferior in strength and durability, cost $35 a ton.[25]

Here then we have a nation of poor farming states, strung loosely along the Atlantic coast line, hemmed in between sea and mountains[26]—in fine, situated

[14] Reuter, E. B., "Population Problems," p. 19.

[15] Reuter, *op. cit.*, p. 36.

[16] Day, C., "History of Commerce," p. 472.

[17] A slight oversight appears here. Further on Day calls attention to the fact that one third of the British merchant tonnage was American built. Here certainly was a "considerable surplus" sold outside the country—in the manufacture of ships.

[18] MacGill, E. C. (and others), "History of Transportation in the United States before 1860," pp. 54–60.

[19] Day, *op. cit.*, p. 486.

[20] Bogart, E. L., "Economic History of the United States," pp. 43–4.

[21] Bogart, *op. cit.*, pp. 134–136.

[22] Clark, V. S., "History of Manufactures in the United States, 1607–1860," p. 18.

[23] Fiske, John, "The Critical Period of American History," p. 137.

[24] Bogart, *op. cit.*, p. 52.

[25] Day, C., "History of Commerce," p. 495.

[26] MacGill, C. E. (and others), "History of Transportation in the United States before 1860," pp. 3–4; also "Cambridge Modern History," Vol. 7, pp. 53–5. Fear, especially of savage Indians, added to the effect of the mountain barrier in confining people to the coast. See Mafvin, W. L., "The American Merchant Marine," p. 1.

geographically and economically much as the ancient Phoenicians on the western shore of the Mediterranean and the modern Norwegians, and, like the men of those two most intensely seafaring nations, early Americans went to sea, not because it was "in their blood," but because there was little else for them to do—save difficult farming.[27] They built up a merchant marine which rivaled Great Britain's—then as now, the largest in the world. The American flag was seen beside the British in every port. . . . Came a great change, this weak, loose-knit string of states became in a short space of time a broad empire: the Appalachian barrier was punctured—the most important event in American history after the Federal Constitution.[28]

Turnpikes and canals were the early outlets or punctures: The Cumberland Road, the first public improvement undertaken by the federal government; the Wilderness Road; the famous Erie Canal, which made New York the commercial center of the nation, and the Delaware and Chesapeake Canal. The Cumberland Road, opened in 1818, was a great national enterprise; the Wilderness Road was mainly what constant travel made it.[29] The first boat passed through the Erie Canal in 1825.[30] Then came the railroads—though the great east-and-west lines were not completed until after the Civil War. Railroads finished, in effect, the flattening out of the barrier which stood between the poverty stricken United States of Washington's day and its richly abundant future, which in the whirligig of time became the background of an unexampled economic power. Railroads made the west completely available.[31]

So formidable did the Appalachian divide appear to the eyes of "the fathers" that sober men, Washington[32] and Jefferson[33]—and later so keen an economist, statesman and business man as Richard Cobden[34]—saw the probability of the weak young nation's breaking its back upon this rude barrier and becoming two separate nations, one erected on either side of the mountains. The establishing of a western empire with himself upon the "throne of the Montezumas" and annexing all territory west of the Alleghenies, it will be recalled, was the foundation of Aaron Burr's treason.[35] The hopes and fears of these men are our warrant for saying that the puncturing of the Appalachian barrier was the most important event in American history after the Federal Constitution. Its effect on shipping was exactly what our hypothesis would lead us to expect. People lost interest in the sea and turned landward to feast their eyes upon a treasure house of economic opportunities, open and at hand.[36]

Why should youth, during the sixties and seventies of the last century contemplate the sea when railways opened to view and grasp almost limitless fields of opportunity: the wheat fields of Nebraska, Kansas and the Dakotas, the oil fields of western Pennsylvania, Ohio and later, of the Southwest, the corn fields of Iowa, Illinois, Indiana and Ohio; the cotton fields of the East-South-Central

[27] It is noteworthy, though the point should receive thorough investigation before it is taken fully into account, that in Virginia where farms were rich and broad, there were few home-owned ships, save bay and river craft or fishermen.

[28] *Cf.* "Cambridge Modern History," Vol. 7, "The United States," pp. 687–696.

[29] MacGill, E. E. (and staff), "History of Transportation in the United States before 1860," p. 7.

[30] Cowdrick, E. S., "Industrial History of the United States," p. 118.

[31] "Cambridge Modern History," pp. 694, Vol. 7.

[32] Fiske, John, "The Critical Period of American History," pp. 212–3.

[33] Morse, John T., Jr., "Thomas Jefferson," Chap. xiv.

[34] *Cf.* Morley, John, "The Life of Richard Cobden," Chap. iii.

[35] Morse, John T., Jr., "Thomas Jefferson," p. 249.

[36] Lord Acton, "Lectures on Modern History," p. 307.

States; then there were gold fields and silver fields, copper fields and vast reaches of timber. Youth in America no longer looked seaward, but went west.

The westward movement of population was under way as early as 1815. There was a light trickle of population over the mountains from the beginning; nevertheless, the American overseas carrying trade continued to grow until 1860. But with the exception of the "gold rush" of 1849, there was no nation-wide appreciation of westward opportunities until, or after, Greeley's day, the sixties and seventies of the past century.

The hands of engineering genius, which broke down the Appalachian barrier, destroyed also America's merchant marine—by destroying the key incentive to the development of an overseas carrying trade, *a scarcity of other economic opportunities.* Engineers opened the way for the development of natural resources and a great industrial economy. Before the progressive process, which we have called the puncturing of the Appalachians, began—a process initiated by the opening of the Cumberland Road and completed by the final consolidation of east-west lines of railway—the United States had the second largest merchant marine in the world, a carrying trade grotesquely out of proportion to economic development in other directions. After the flattening of the Appalachian barrier, and just before the World War, the American flag had almost disappeared from the high seas. It was represented by a scant million tons of shipping.[37] Had overseas shipping continued to develop even as fast as foreign trade (imports plus exports), the United States should have to-day a merchant fleet of twenty-six million tons.[38]

[37] "Statistical Abstract of U. S.," 1926.

[38] Foreign trade (exports plus imports) in 1913 amounted to ($4,278,000,000) twenty-six times as great as in 1800 ($162,000,000) when the American merchant tonnage was just short of one million.

What then of the future? Prophecy is always dangerous and often profitless. But prediction is the purpose of all science. The chemist studies molecules and atoms, their qualities and behavior, so that he may predict what will happen when they are thrown together in certain proportions. The physicist studies force and matter that he may predict the consequence of a certain application of force to matter. The sociologist, the economist and other social scientists study human interplay so that they may predict how men and their social contrivances will react in their various relationships. Only by prophecy, then, can we escape the charge of futility.

If we apply the hypothesis that a nation develops a notable overseas carrying trade only when opportunities for economic activity are wanting or have become exhausted, it seems patent that if the United States is to acquire a merchant marine to match economic development in other directions, the process will be a slow one—or an artificial, stimulated growth.[39]

Though outlets for economic activity in the United States are far from being exhausted, the first cream has been skimmed, and the second skimming is in process of collection. This exhaustion, or preemption, of economic opportunities forms the foundation of a present growing interest in overseas shipping—an interest which in the nineties of the past century even Senator Hanna, with his singular political power and enormous business prestige, was unable to stir up.[40] Americans of the second quarter of the twentieth century are beginning to look seaward; and it is conceivable that a nation which in its infancy competed for shipping primacy may in the full strength of maturity compete again.

[39] Presidents Harding and Coolidge, shrewd judges of the drift of public sentiment, both favored the granting of ship subsidies.

[40] Croly, Herbert, "Marcus Alonzo Hanna," Chap. xxii.

SELECTION AS A FACTOR IN HUMAN EVOLUTION

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SELECTION is here used in a very broad sense. Millions of words have been written on natural selection since Charles Darwin's time, and to these mountains of literature nothing need here be added save the conviction that natural selection of some sort was among the instrumentalities used in making man what he is. In spite of changed conditions it will always have to be taken more or less into account in the changes yet to be wrought in man and his world.

We are just arriving on the threshold of selection in its comprehensive and most useful form. It is only as man trains his selective faculties more highly and learns to use them more constantly and in all the multifarious departments of his personality and his environment that his evolution can continue to its logical perfection.

The wizardry of artificial selection in the making and improvement of our splendid domestic animals, fruits, vegetables, grains and flowers is one of the most fascinating themes, one of which we never tire, yet it can never be fully told, for much of its most thrilling portion is in the unrecorded past. In honor to this great agency, through which we possess the foods on which we depend each meal of each day of our lives, every one with a garden should consecrate a few more moments to the selection of seeds, and therefore to the study of his individual plants to select the seeds from the most vigorous, disease-resistant, most productive and, above all, those of distinguished quality. A very few seasons of such selection yield most pleasing improvements, the plants also becoming better adapted to your local conditions through the generations. Personally I grow all my own garden seed, and count that the most interesting part of my garden work.

Natural selection and artificial selection possessing such vast and unique powers, we must realize that in the selective principle, taken as a whole, lie untold possibilities, of which we have only observed a little, and whose rich storehouse of treasures we have only begun to mine.

During many ages a wise man now and then has suggested the value of selecting the thoughts that we think. To-day some suggest that we should rigidly select and reject in the matter of reading. Occasionally we even hear of a person who deliberately selects the environment in which he cares to live, and who then steadily tries to change it to make it fit his ideal even more closely. In fact, the difference between the exceptional person and the average person to-day lies in whether he takes his thoughts as they come, his surroundings as he finds them, and acts in the ways requiring the least thought or selection; or whether he is esthetic and enterprising in these matters.

Energy must be spent in living, whether we will or no; why not then spend it walking the most beautiful paths to a definite goal, instead of continually wallowing to get out of pitfalls? Selection, or the lack of it, will make all the difference. Just as one example of this, one man sees much of the race burdened with excessive sex impulses; he blames the Puritans for it, and says it is a reaction from their teachings; when, if he had read more intimately in the literature of the past, he would see beyond all doubt that the race has always been thus burdened since the beginning of history; and if on top of this he would

study the whole world of living things, comparing the one species, man, with all the other species of animals and plants, he would be led to the inference that the race had been thus burdened in prehistoric times, ever since the beginnings of leisure and the unwise selections in the use of leisure.

Increased leisure doubtless came to man when, through his increasing intelligence, his food supplies were increased, stored and otherwise made more dependable.

The happiest use of leisure remains one of our major problems. Maybe it will never be well solved by or for the masses. It may often be erroneously solved by upper classes. One who knew well what is in man said that many travel the way to destruction, but few the way to life. The few do some selecting, the many do not.

The solution of one's leisure problem depends on the training and experience of his selective faculty. The same is true of his problems of work.

By the method of "trial and error" the one-celled protozoan, like the average man, flounders around in a hit-or-miss fashion.

The exceptional man selects his thoughts and his acts and thereby builds for himself a fortune, a garden or an education. One person has a fine character: it was made by judicious selection. The old book of Deuteronomy tells us that life and good and death and evil are spread out before us, and counsels man to choose life, that both he and his seed may live. Selection, and unrelenting selection, each day and at every turn in life, is a part of the price one must pay to live well.

Keen perceptions, good powers of observation, clear vision, both physical and mental, seem essential to judicious selection. Unfortunately not every one is naturally gifted in these respects. This doubtless is responsible, in part, for the scarcity of those who exercise selection. The present, the near and remote future loom bright to those thus gifted. Some even possess such clearness of perception, such almost unerring accuracy as to savor of the spiritual, of something, like starlight or sunlight, from above our ordinary horizon.

Genius strikes our race in many surprising forms. The well-rounded man should be a genius in every trait which possesses lasting worth. The future evolution of man must produce some ideal human beings. Elimination will doubtless be very effective in raising the general level. The elimination, in some way or other, of the many who have eyes but will not see, and ears but will not hear—who will neither perceive nor select aright in the important things of life—is both scriptural and highly scientific. In the improvement of men or fruits or flowers by selection, the very best are considered, the rest are disregarded. But it is all too easy to err in such discriminations. The neglected stone or the lost sheep may prove truly superior, and at the same time prove how defective is our judgment in these matters. Yet there can be no doubt that there are countless human dogs that never appreciate things choice or holy, and human swine who would but trample on the rarest pearls of thought or action and do injury to those offering them the opportunities.

The human tree which can not by its intrinsic nature bear good fruit is hewn down. Pruning, fertilizing, educating and moral suasion can not, we are told, do the trick, in many cases. To avoid the possibility of wronging any through errors of judgment, the whole human race should be given opportunities to show what they are, and what they may become under favorable circumstances. But this very act will require forceful restraint of hordes of vicious, bad folk whose deeds, and whose very existence are so wicked as to prevent the fair treatment of the worthy. Far more

human souls have been hurt by the wicked than by errors in judgment of the well-meaning.

Selection of environmental factors is of tremendous importance in the continued evolution of man. Selection of hereditary characters is, of course, more fundamental, but the environment is often all too potent in repressing the best traits, or rendering impossible the exercise of choice gifts. The very best surroundings possible can be none too good for the development of the ideally gifted man. There is an old saying; the greater the man the greater his temptations; so that I fancy that such superior beings as may be developed in future will have enough to try them, enough to develop their characters, even in the best of environments.

Our surroundings in this world can hardly be too carefully selected, too comfortable, too healthful, too beautiful, too inspiring. Even when the ideal in these matters has been approximated, the greater constructive tasks, which shall by then have arisen, will be enough to tax to the utmost the larger powers of the men and women of the time. Such times will not be dull and monotonous, as some are wont to predict, but will be beyond our present power to conceive in interest, in difficulty and in rewards. Alarmists have always abounded to warn of the dangers of the great waves or milestones in human progress. Many were those who predicted evil from the widespread introduction of machinery and inventions and discoveries. Numberless scholars in past times have conscientiously opposed the education of the masses.

Our civilization is advancing to greater heights at a speed unknown in former times. This is due to greater concentration and larger cooperation along constructive and scientific lines. In these constructive enterprises the demand for really first-class men is more than double the supply. The rapid improvement of our environment requires a greater supply of such superior personalities; therefore, in order to effect this greatly desired improvement in our environment we must find a way to raise the caliber and increase the number of truly first-class people. The work can not be done rapidly and efficiently without them. We are all convinced that our surrounding conditions of life must be improved. We sometimes even find a person who finds fault with other *folk*. Something or somebody must be improved. The development and improvement of our constructive and scientific civilization, therefore, is one of our most visible motives for selecting more and better organizers, creative workers, scientific thinkers, inventors, seers.

True progress, however, exists for man, rather than man for progress. At our present stage of development, however, it is easier for most people to realize the need of improving our surroundings than to see the need of changing man himself. This does not matter as much as might seem to some, for both the improved environment and the improved race are absolutely necessary, and the one can not be had without the other. Try as hard as we may to improve our surroundings, we are up against a blank wall, so far as really lasting improvements go, unless we also improve the improvers. Many of our fondest educational schemes have proved but empty bubbles. Hundreds of brains have toiled for years over social and political panaceas which have but crumbled to ashes. No amount of digging and educating, fertilizing and training, cultivating or pruning will make a valuable and fruitful orchard if the trees in it are intrinsically or innately inferior or mediocre. We can not get good fruit from bad trees nor good results from inferior people. There is no educational nor political panacea to fit their case.

A corrupt society, a mistaken, hazy, superstitious and erroneous atmosphere

will always surround foolish or semi-foolish people. This hazy mental atmosphere not only surrounds such social groups, it emanates from them. It is a natural by-product of their mental metabolism. All of us, unfortunately, have some of their blood in our veins; while the average man has far too high a percentage of it.

It can hardly be said that there are any human thoroughbreds; even the best and smartest families on earth have made too many errors of judgment in their matings. In searching their ancestry they do not have to search far before running across some careless, impulsive matrimonial blunder, and an ancestor has been added to the line who brings more of burden than uplift to his or her descendants for indefinite generations, until, by chance, the genes are so divided up that some descendant, more fortunate than the rest, may fail to get one or more of the undesirable hereditary traits. But he is equally liable to fail to get some of the best traits.

We will have to grade up from the best "grades" we have, in our effort to produce more intelligent, more beautiful, more disease-resistant, more altogether superior human beings. What better can we do if there are no true thoroughbreds? Is it *possible?*

Fortunately, some of us wholeheartedly believe in a great personality who created all the heredity scheme, and everything else in the universe. We believe this all-perfect and all-powerful Being can make possible to those who believe, and who add to their faith works —(to the utmost of human knowledge and power)—many things which might otherwise be impossible without such faith and knowledge and works. If we do not use what brains and what science we now possess toward making better brains in the future and better science, we may expect to have what brains we have and what knowledge we possess taken away—like the one talent hid in a napkin—and our opportunities given to those more worthy and more gifted than ourselves.

Could it be possible, we repeat, by judicious selection on the part of the best human "grades" to grade-up, and eventually to produce real thoroughbreds? For answer take a look at what has been done in flowers, fruits, animals and grain, starting only with wild grasses, wild beasts and weeds.

But there has been much selection, painstaking selection, even indefatigable study of the organisms in the process, leaving no trait unobserved, unsought or ill-considered. So it must be with the human pedigree. Most patient selection, and—far more rejection.

In this matter of selection there are certain relations between pedigree and performance which are very simple and yet ignored entirely by many. Individual traits and individual performance are well worth considering. No fine person could wish to marry any one who was not entrancingly lovable, of fine appearance, strong, highly intellectual, clean physically and mentally and morally, full of life and fascinatingly interesting. Such a person would never care to marry a paper pedigree, but would require to fall in love with a real person whose individual personality and individual performance excited admiration and inspired love. But such a superior individual is pretty sure to be the product of many fine ancestors whose individual performance records average very high. Very well; let this pedigree be studied with painstaking care and patience, and if it be so proved, then to one's personal estimate of the lovable individual is also added a substantial guarantee that in this individual is a solid, substantial worth that will show itself both through the years that are ahead and through the ages yet to come, a foundation of lasting worth on which may be built yet fairer mansions for the souls of future men

who will look back to you, their forebears, and truly honor their fathers and their mothers, that their days may be long in the glorious land which the Lord their God is to give them.

Performance to-day is pedigree of to-morrow. This is one of the simple relationships between pedigree and performance. Your performance to-day actually becomes part of your offspring's pedigree. Your individual performance record is a very substantial part of your individuality. It is very largely what you will be judged by by your great-great-grandchildren. The great-great-grandchildren of others will look it up in estimating your descendants. This will be done far more in the very near future than it is being done now. It is a part of the rapidly growing scientific lore of to-day which will become a part of the *life* of to-morrow. Many new things which we barely reach toward to-day will become deeply ingrained in the life of to-morrow. As tomatoes and oranges but a short time ago were tasted sparingly by a few of our forebears, but to-day are part of our substantial diet, and as electricity, steam, gas-engines and airplanes come rapidly into integral relationship with former essentials of the foundations of our life, so also will many other ideas and practices which to-day seem a bit hazy to some, or entirely beyond us to others.

So that even though the ancestry of a high-grade human being of to-day may not be altogether to his liking, let him remember that so far as he or she individually is concerned he can make his own personal part of his children's pedigree very excellent. This he will do by an individual performance record of the highest order both in what it omits and what it includes. He will sedulously omit everything from his life and even from his thoughts which a far more scrupulous generation than our own might take exception to. He will include daily deeds of such nobility and worth to his generation as to raise him greatly in the esteem of God and man. He will add, to the utmost of his ability, to his education, to his physical strength and health and appearance, to his material wealth as so much added power for good, to his success in business, in his profession, or as a statesman, to his capacity for service both to man and to the Kingdom of God —in short, to his whole physical, mental and spiritual make-up. With this lofty individual performance record ever as his aim he will go forward and upward along the path of life more joyously and more richly than his less gifted companions who may be plodding along more selfishly and without the forward look into the better ages yet to come.

Selection demands our attention at every turn. Selection in the important things, selection in the little things, selection every moment of life. As the wild song-bird must keep its eye ever open for a hundred creatures of the earth and air that are ready to do it harm, and at the same time seeks most skilfully for food for itself and for its young, and also rejoices with full heart in all the beauties of nature around it, so man has to select and to reject or avoid, in little things and in the most important, in his daily and hourly habits and in the supreme and unique crises which may come but once in a lifetime. Woe betide the luckless one who on an impulse enters blindly the great crisis of life and throws away his birthright.

Foolish also is that man or woman who, either before or after the great event of marriage, squanders wastefully the sublime energies of life's sacred fires. Biological science of to-day reveals the greatness and sublimity of these vast reproductive forces. Such a trifler brings to life's sacred altar but the fag end of a worn-out potential parent, and too often deprives his offspring of the choicest free-gifts of the universe, gifts which no after education or wealth or food or medicine or travel can ever re-

place. The big deception of it all is that persons think they are marvelously enriching their lives by what really robs them of life's hidden wealth. Some of the biggest lies are ever being sown the world around by people who *ought* to know better, and by some who *do* know better but delight to deceive themselves and others. Selection will deal roughly with all such—some day, "if not before."

Happy the person who from infancy begins to select beautiful interests—flowers and birds, mossy rocks and sunny fields, butterflies and crystals, mountains and stars, poetry and music! Twice happy the child who, in addition to these wholesome, growth-giving environmental factors, comes up also in an atmosphere of *stimulating* religion! Whatever may be said in favor of the various great religions of the world, there seems to be but one that offers incentive to personal development, physical, mental and spiritual, along most wholesome, natural lines, to a goal of absolute perfection and divine completeness and power and righteousness, peace and joy. Other religions may have their excellent points, or the reverse, but no other furnishes the incentive and stimulus to the highest endeavors and attainments foreshadowed in the dominant religion of the leading civilizations of the most scientific and progressive portion of the human race to-day.

The child brought up in an abundance of pure air, with much outdoor life and direct sunshine, plenty of fruit, vegetables and milk all through the year, with steadily growing interests in nature, and living in a home atmosphere of the highest mental and spiritual stimuli, will early have his selective faculties developed and strengthened.

By constant daily use the selective gift may grow, under the best guidance, to a point of unerring accuracy almost uncanny, almost supernatural. On reaching youth, and later on reaching maturity of full manhood and womanhood, people thus fortunately conditioned would choose, as by second nature if not truly by first nature, those interests and occupations, those companions and thoughts, those places of amusement and exercise, and finally those professions and life-partners which would be alike most beneficial to themselves and to the world. They would naturally shrink or recoil from all destructive or wasteful thoughts, practices and associations, be repelled by vicious factors and foolish impulses from within or suggestions from without. The unsavory would escape them. Gloom, despondency and weakness would have no part in their personality. As individuals, their life curves, correctly plotted, would soon turn up toward the infinite zenith. As families, through the generations, progressive improvement toward a race or group of ideal people in beauty and perfection of body and also of mental and spiritual endowments and activities would be theirs.

It is wise selection which makes one man rich, while the lack of it finds another man poor; one man strong, while another is weak; one man radiantly joyous, while another is sad.

Each individual, in selecting constantly and continuously the elements which make up his environment, association or companionship, and the stimuli of his thoughts, may make the most or the worst of what his ancestors have passed on to him as the result of their mate-selection in the past. The same individual, by judicious mate-selection, may pass on to his children improved, or at least unimpaired, the gifts of his ancestors. He may thereafter by wise selection surround those children with an approximately ideal environment—with the aid of a well-chosen mother for the children. If then the judicious choice is repeated or improved upon through the succession of generations, making use not only of individual judgment, taste,

etc., but also of pedigree and other records, the good traits will be strengthened and increased in number, while bad or weak traits, resulting from careless or uninformed mate-selections in the past, may in time be practically bred out from the stock.

I would not be misunderstood as claiming that an individual's performance-record can be inherited by his children. Neither can his good environment benefit them directly unless they also share it or a better one which may be the logical outgrowth of it. But I do claim that an individual's performance-record becomes his personal contribution to his pedigree, and is valued by his descendants and their relatives according to its quality, as indicating what his inherent qualities were capable of performing and indicating also that these same capacities may be coursing in their own blood or imprinted in their protoplasm, either diluted or reinforced. In this respect personal performance is of far more value to students of heredity than some have realized. As a true index of the possibilities lying within the hereditary qualities of an individual, what could be better than the accurate record of his performance? And this performance may be developed to its highest and finest possible or may be neglected or even largely ignored by the individual throughout his whole life. I am personally acquainted with some men of unusually fine mentality, men who also possess sufficient health and strength to back up their minds in great achievements, yet who are spending their whole lives as nonentities. Such bright men can not help knowing that they are peculiarly gifted. Two of them admit frankly that they are too lazy to achieve anything great. The others fall back on that worn-out and insufficient excuse that they had had very little schooling. That, of course, is arguing in circles. Schooling can be got by those who have the mind and the will, or it may be given to oneself, for there is no schooling like that which comes of itself along with actual achievement of a high order. Not only hundreds but thousands of men have demonstrated that they could fairly devour knowledge which they most needed right in the course of a very busy life of achievement.

There is no excuse for allowing any good hereditary gift to lie unused or only half developed. He who practices well the faculty of selection which I am advocating will search thoroughly his own physical, mental and spiritual make-up to see if there is not some good quality or possibility within him which he may have overlooked in former similar surveys. Here also he will be aided by research into his pedigree, or the performance of his ancestors, which may call his attention to inherited characters within himself. This may show him a reflection of himself from a new angle. At the least he will be honoring his father and mother by taking the pains to find out about them, and about their fathers and mothers, as far back as faithful search can reveal anything. It is a respect which everybody owes his forebears. Let it not be put off, then, with that trite and flippant excuse for human indolence, "Oh, I am not at all interested in genealogy."

But the things which by wise selection one *omits* from his life are nearly as important as those he *includes*. Sometimes they are fully as important as the inclusions. Certain poor or worthless elements, habits or thoughts may, if included, actually inhibit or repress valuable elements, habits or thoughts. Those who have their selective faculties highly trained through constant practice find that in order to develop certain valuable elements in their complex to their highest degree it is positively essential to drive out or to smother other elements.

Viscount Rothermere, one of the world's greatest newspaper men to-day, and Mussolini, one of the world's greatest organizers to-day, have each pulled

out two threads from the fabric of their lives, as indicated by Rothermere's account in the London *Daily Mail*, and reported by the New York *Herald Tribune*. While in Rome Rothermere visited his friend Mussolini. In his account he comments upon Mussolini's executive capacity and memory. He then says: "Strict self-control and economy of time are the secrets by which this high standard of efficiency is achieved. . . . He sleeps eight hours a night. For ten years he has not taken a drop of alcohol. He does not smoke. He regards alcohol and tobacco as entirely unsuitable for people who have hard mental work to do." Rothermere then adds: "His opinion confirms my own experience and practice, for out of regard to the heavy responsibilities resting on me I have been for some time past a teetotaler and a non-smoker."

These and other omissions on the part of the selectively trained, for the sake of high achievement and great efficiency, may prove to be the negative concomitants of the positive virtues they so highly prize. The really electric, vital man who *does things* requires both positive and negative electrodes. The nonentities neither positively develop anything in their lives nor negatively repress anything. They do no selecting. All nature cries "Select!" but they growl, "What's the use?"

"Marry in haste and repent at leisure" is a motto voiced by many throats daily, in one part of the world or another. It is the belated awakening of a bit of the selective faculty.

"Love is blind," some say, but with eyes wide open during the love-making, and the mind doing some scientific investigation of the ancestral history of the parties concerned, the love may be truer, deeper and more enduring.

We are immeasurably indebted to hundreds of unknown benefactors who have selected and produced many cereals, fruits and vegetables on which we now depend. This work was done partly by our own ancestors, partly by natives of various lands. For example, we owe to pre-Columbian natives of the Andes such valuable staples as the potato, sweet potato, peanut and tomato, and the size and some other valuable qualities of our cultivated strawberries. Our own ancestors had been cultivating very small and soft berries prior to crossing these with the large, firm berries cultivated by natives of Chile.

The same scientific, selective process which we employ in educating our minds, building gardens of lovely environment around us, choosing ideal climates, filling our hearts with joy and beauty in place of haphazard commonplaceness and developing fine fruits and other foods from wild plants of field and forest—this same judicious selection applied to our own species has power to improve us physically, mentally and spiritually, and render us capable of selecting our environment and our flowers, vegetables, grain, sugar cane, rubber trees, livestock, fruits and mates even more wisely in future than our race has done these in the past. We can hardly start training our esthetic faculties of discrimination in all things too young. This is general selection. Natural selection, like wild fruits, nuts and roots, is good in its place; we may never know how much we are indebted to it; but voluntary, intelligent selection in all things which may add to the value of life is incomparably better for us from now on.

GREENNESS AND VITAMIN A IN PLANT TISSUE

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THE term "vitamins" is comparatively new in the vocabulary of science and in common parlance. The use of this term has become surprisingly universal in an amazingly short time. At the thought or mention of it a sense of mystery and wonder creeps in, and such common commodities as cod-liver oil, yeast, milk, oranges and carrots arise into consciousness as lowly things of vast consequence. However, though we have coined and popularized the term, are using it to name an elusive something which seems to be present in certain food products, and are profiting from an increased use of these products, our generation can not claim the distinction of having first learned that there are certain edibles in nature which have a peculiar function in the promotion of human growth, health, strength and longevity. History often serves as a curb which is effective in the discipline of modesty. Green plants, most of which are classified as vegetables, have served the race a good while, and, what is more, have long been recognized as having nutritional virtues exceeding those to be expected on the basis of their ordinary chemical composition.

In ancient Rome there was a great naturalist who wrote some valuable works on plant life. His name was Pliny. In one of his books is to be found the following story. The Emperor Augustus was dangerously ill. His death seemed certain. Lettuce as human food was in existence at that time. In fact, lettuce as a salad plant seems to have been raised as far back as we have any authentic history of mankind. It was served at the tables of the Royal Palace of Persia in the sixth century B. C. and was present in China in and probably before the fifth century A. D. Well, Augustus had a craving for lettuce, but his physician would not prescribe it for him. In that case, he adopted a common American custom, namely, dismissed the doctor and retained another, whose name was Antonius Musa. This physician, being more intelligent or else more cunning, immediately prescribed lettuce. The emperor ate it with abandon and promptly recovered. The commons of Rome showed appreciation by erecting a statue to the physician in one of the public squares of the city. This happening gave such publicity to the lettuce plant that it was made a part of the diet of the people everywhere in the nation. They used a substance called "oxymel" to preserve lettuce that they might have it at all times of the year. The preserved product was known as "Meconia" and was nearly as potent as the fresh material. Pliny remarked of his own accord that the lettuce of the day contained an abundance of soporiferous milk, was somewhat blackish in color, had a cooling nature and that in the summer it was very grateful to the stomach, freeing it from nauseation and giving a good appetite.

The disease known as "scurvy" was the main causal factor leading to the trial and use of vegetable products as specifics for disease. While scurvy is related to Vitamin "C" rather than "A," some incidents from its history will serve to draw attention to the fact that long ago the general and also more or less particular value of fresh green vegetables was recognized.

No history of medicine could be complete nor even acceptable if the name of John Huxham (1692–1768) were omitted. In his famous "Essay on Fevers" he differentiated typhus from typhoid fever. He was the man who prepared tincture of cinchona bark. His "Essay on Antimony" is a classic. Strange as it may seem, when, in 1747, twelve hundred of the seamen of Admiral Martin's English fleet were down and disabled with scurvy, Huxham recommended that they be put upon a fresh vegetable diet. His prescription was a success.

The value of fresh vegetables for seamen became more and more evident to other physicians of the times, notably James Lind (1716–1794). Lind was surgeon in the Royal Navy (1739–1748). He is referred to as "the Founder of Navy Hygiene" and as the "Father of Nautical Medicine." Something had to be done, for scurvy was putting the English navy out of commission. Lind saved the day by his insistence upon the seamen being fed citrus fruit juices and fresh vegetables. Largely through his influence the English government was finally led to officially include these items of daily diet in the ration of the navy.

Below is given an extract from the personal memoirs (Vol. 1) of General Philip H. Sheridan, U. S. A. It is an episode from his life while he was stationed at Fort Duncan, Texas, in 1854. Speaking of this experience in the southwest the famous spokesman for the words, "Turn, boys, turn, we're going back," says:

> During this period our food was principally the soldier's ration; flour, pickled pork, nasty bacon—cured in the dust of ground charcoal—and fresh beef, of which we had a plentiful supply supplemented with game of various kinds. The sugar, coffee, and smaller parts of the ration were good, but we had no vegetables, and the few jars of preserves and some few vegetables kept by the sutler were too expensive to be indulged in. So during all the period I lived at Fort Duncan and its subcamps, nearly sixteen months, fresh vegetables were practically unobtainable. To prevent scurvy we used the juice of the maguey plant, called pulque, and to obtain a supply of this anti-scorbutic I was often detailed to march the company out about 40 miles, cut the plant, load up two or three wagons with the stalks, and carry them to camp. Here the juice was extracted by a rude press, and put in bottles until it fermented and became worse in odor than sulphurreted hydrogen. At reveille roll-call every morning this fermented liquor was dealt out to the company, and as it was my duty, in my capacity of subaltern, to attend these roll-calls and see that the men took their ration of pulque, I always began the duty by drinking a cup of the repulsive stuff myself. Though hard to swallow its well-known specific qualities in the prevention and cure of scurvy were familiar to all, so every man in the command gulped down his share notwithstanding its vile taste and odor.

These and other early and even ancient observations on the singularity of certain plants as possessors of a something that is very essential to the normality of the human organism are very interesting. Remembering, though, that human creatures in general have always had "the will to live," have always insisted on living the longest possible time and have ever sought desperately to remain in the best of health while living, we should not be surprised at what history reveals. It could hardly be expected that the race should have failed until now to stumble onto parts of the vegetable kingdom as sources of prevention and cure for some of the dreaded ills that have ever been in close pursuit, threatening to extinguish the species entirely. The crude yet quite effective method of "trial and error" was in operation long before the dawn of what we are pleased to term "The Scientific Era."

Not until the latter part of the nineteenth century did real scientific inquiry into this fascinating question begin. The splendid investigations of Eijkman (1897) pioneered the way. These were

followed by the works of Hopkins (1906) and those of Holst and Froelich (1907–1912). The theory of vitamins or the necessity of one or more unidentified accessory factors (present in certain edible materials) for normal nutrition was originated, and as a theory has held the field against all others that have been proposed. And, at the present time, though we do not know exactly what any one of the several vitamins (A, B, C, etc.) is, either chemically or physically, the evidence at hand is sufficient to make their reality seem overwhelmingly probable. We believe in them hypothetically.

For the purpose of the present article the so-called Vitamin A may be selected out for special attention. It is referred to usually as the growth vitamin. In general, though not in particular, the definition is correct. On diets deficient in Vitamin A the expert diagnostician notes several symptoms of disorder in the animal organism, while the outstanding, summarized, clearly visible consequence is the lack of growth and even sharp losses in weight. Death may result if the deficiency of the vitamin is extreme and continuous for a relatively long period of time. Its significance is great enough to cause serious concern regarding its location in nature.

Fresh vegetables constitute one of nature's richest storehouses for Vitamin A. This fact has been adequately proved and now the recommendation of fresh vegetables for the diet of the human being, especially when still undergoing growth, is made universally in all civilized countries. This is well and good, but it should be emphasized that species of vegetables are quite numerous, that they vary considerably in Vitamin A content, and, furthermore, that there are many ways of preparing these products for the market, for preservation and for being served at the dining-table. Celery is offered to the consumer in the bleached state; lettuce as green leaf lettuce and also as head lettuce, where the greater part of the head is only slightly green to entirely non-green; tomato fruits as they come ripe from the plant and again after having been picked green and ripened artificially with some sort of heat or gas treatment; asparagus is sold either fresh or in cans in both the green and the bleached state. These conditions have raised a number of questions, among which is that of the relative merit of a vegetable when bleached as compared with its value when green. Undoubtedly, the bleached product often looks more attractive, is more succulent and brittle, has a nicer taste, is more suitable for some of the fancy notions of the chef, and, on the whole, serves the aristocratic ambitions of the persons concerned more efficiently. But, does it have equal quality as a nutrient material? All evidence obtained thus far goes to show that the green product is far superior to the non-green.

Experiments conducted in England have shown that the inner whitish leaves of the cabbage head are very poor in Vitamin A, while the outer green leaves are rich in this respect. Through other experiments it has been demonstrated that the stalks of bleached celery contain no more than traces of Vitamin A. This vitamin is also deficient in the inner leaves (the bulk of the head) of head lettuce, and in the innermost yellowish leaves is probably entirely lacking. At Michigan State College we have conducted some experiments wherein the Vitamin A value of green and bleached asparagus in the diet of white rats has been determined. The results have not been published in technical form as yet, but were reported at the meeting of the American Association for the Advancement of Science held at Nashville, Tennessee, in December, 1927. These experiments demonstrated that when growing asparagus is covered over in the row

with soil and the tips cut before they reach the surface and become green by exposure to the sunlight, their value in terms of Vitamin A is very low indeed. Animals fed on the fresh white tips lost weight, became badly diseased and died before the end of the sixth week, while other animals receiving an equal amount of fresh green tips were healthy, vigorous and gained weight at the rate of about five grams each per week. Approximately the same result obtained with other groups of animals where the two kinds of tips were cooked before being fed. In still other lots of animals canned green and canned white tips were fed, the daily amount of the white being double that of the green. The increased quantity of the bleached did not suffice to give growth or even prevent death, while the animals on the canned green tips grew in normal fashion.

Clearly, it seems that there is some connection between greenness in the foliar tissue of vegetable plants and their content of Vitamin A. Just what the nature of this association may be is as yet an unsolved problem. Scientists wonder if the green pigment or some part of its chemical make-up is itself the vitamin, or if the presence of the pigment is essential to the synthesis of the vitamin in the tissues of the plant, or if the pigment is merely coincidental as a side development in those conditions of environment in which the plant manufactures the vitamin. Their wonder is leading them to erect hypotheses and to perform laborious experimentation in an effort to unravel the mystery. True enough, in a few cases animals have been made to grow when fed seedlings which had grown under conditions that prevented their becoming green, but it required daily quantities of the material which were many times greater than necessary of green seedlings. And furthermore, there is the possibility that the potentially green pigment bodies are present in such tissues in a colorless elementary state. In time, the deeper secrets will be revealed. Modern biological research is very aggressive and has already made a record that justifies confidence in its future.

At the present time, though much has been accomplished, it must be said that as regards the question of almost any one of the several vitamins perhaps only the threshold of inquiry and discovery has been crossed. Further progress in the task of revealing the nature of the relationship between greenness of plant parts and their Vitamin A quality will hinge in part, perhaps in the main, on fundamental research with the green pigment itself, which is known to the botanist and chemist as "chlorophyll." A good deal is already known about it, but all this is probably meager compared to what is not known and should be learned. It is made up of carbon, hydrogen, oxygen, nitrogen and magnesium in the general proportion of $C_{55}H_{72}O_6N_4Mg$. The structure of the molecule is very complex and need not be discussed here. It exists in the normal green leaf in at least two slightly different forms or varieties which are not exactly the same in either structure or proportion of chemical elements. Basically, it is an organic acid of the tricarboxylic type combined with two alcohols (methyl or wood alcohol and phytol alcohol). Due to this fact, it is classed as an "ester" and belongs in that great general group of compounds which contains, roughly, such familiar things as butter, tallow, olive oil, beeswax and most of the artificially manufactured fruit essences. Generally speaking, chlorophyll does not form in the leaf in the dark and is less in plants heavily shaded while growing. It does not form unless iron be present in the plant cell and carbon dioxide in the atmosphere surrounding the plant. Plant parts without chlorophyll are incapable of

manufacturing the sugars that are synthesized in these parts when they are green and exposed to light. Though leaves contain sufficient chlorophyll they do not function in food manufacture unless they are exposed to light. In some mysterious way chlorophyll manages to capture, transform and render available the energy contained in rays of light. All this seems like a good deal to know. But really, it may be a mere beginning of knowledge. Why are these things so? How do they come about? If chlorophyll in either an elementary or finished form is indispensable to the production of Vitamin A in plants, we as yet have hardly the slightest inkling as to just what the subtle connection and process is in its details. Once such information has been mined and systematized the synthesis of the vitamin in the laboratory may be possible and its function and employment in the diet of human beings be rendered more intelligent.

In the meantime, while we wait upon science, it is well to eat fresh vegetables and still better to prefer that these be decidedly green in color, when it is the foliar part of the plant which is used. That last clause is inserted lest it be forgotten that with a good many vegetables the edible portions are not foliar in character and are not green. Examples of this are the fleshy roots of the carrot, the beet and the radish. Are these to be excluded because they are yellow, red and white rather than green? Certainly not, for experiments have shown that they contain the vitamin factors. They were produced as parts of plants whose tops were green. The food substances they contain were built up in these tops and transported to the roots for storage, and likewise the vitamins that are known to be there. Milk, butter, cheese and other food products coming from domestic animals are not green and yet they afford Vitamin A. The answer is apparent when it is recalled that these are herbivorous animals in part or entirely. The amount of Vitamin A in cow's milk and consequently in the butter made from this milk varies with changes in the pasturage or the plant roughage furnished for the cows.

This article should not be concluded without the addition of two or three paragraphs that are somewhat critical in nature.

Scientific discoveries usually arrive at the stage of completion by slow degrees. Oftentimes, as in the case of the vitamins, long before investigation has been concluded the discovery becomes known to and is appropriated by the public. Frequently the new thing creates more or less of a sensation. It is adopted at once and in a manner more or less fanatical. We may, in our great enthusiasm, run past the limits set by the lack of more complete experimentation and understanding. When so, we take the risk of useless worries and costly mistakes. Many who have insisted prematurely on the X-rays, radium emanations and ultra-violet light have had no benefits or else got burned by "playing with the fire." The point is that even though fresh green vegetables have been proved to be rich in Vitamin A, and some of the other vitamins as well, it is unwise to become so excited about it that we overdo the eating of them, in the sense of throwing the diet out of balance. Food products other than green vegetables afford Vitamin A and are imperative for certain additional properties not common to green vegetables. Every vitamin is essential, but the foods containing it are required for other reasons as well. Because of this there must be a variety with the several individual items therein properly selected and correctly proportioned. This having been accomplished, the all-important vitamins, as best we know now, take up as a part of their duty the task of acting as stimulators which serve to facilitate and regulate

the biological processes in which the foods that afford energy and give tissue building material are digested, absorbed, distributed and assimilated.

Secondly, it is apparent that there is a tendency to misjudge the relationship of vitamins to nutritional disorders. No doubt vitamin deficiencies are responsible for a great many of the troubles which human beings experience, but not all, for it should be remembered that there are at least some major and minor disturbances and irregularities with which vitamins may have little or nothing to do. Vitamins are not magic cure-alls for any and every sort of ailment that can occur. The need for expert diagnosis and treatment of nutritional troubles is not less but greater perhaps than ever before. Multiplied remedies demand increased knowledge and wiser prescription. As the last sentence in his book on "Scurvy" Dr. Hess used the following: "There is a growing danger of attributing every unexplained nutritional disorder to the new, overworked but ill-defined vitamins—of their sharing with the secretions of the endocrine glands the fate of becoming the dumping-ground for every unidentified disorder." While progress in an understanding of the vitamins and their rôles in human nutrition has been made since this book was printed, the danger to which the author alluded has not disappeared. Ideal advancement is that type which is mixed with a degree of conservatism that is sufficient to make changes in practice wait upon the presentation of incontrovertible evidence of fact.

MALARIA AS A FACTOR IN ITALIAN ENVIRONMENT

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ITALY has long been the classic land of malaria. From whence it came or when introduced is not known, but that it was well established in the Peninsula long before the Christian era is certain. For at least twenty-five centuries it has taken a heavy annual toll of life,[1] and the economic loss through decreased efficiency of labor and reduced utilization of areas subject to the disease have been enormous.[2] Even to-day one third of the total area and 40 per cent. of the population of the entire Kingdom are in communes officially "malarial." The number actually living in the infected *parts* of such communes is about 12 per cent. of that of Italy or about four million people. The number of cases "officially reported" annually runs over two hundred thousand and it has directly or indirectly affected the social and economic welfare of the whole population.

In the centuries following its introduction into Italy devastating wars, both civil and foreign, by discouraging agriculture and especially by their destruction of the irrigation and drainage systems, caused much of the cultivated land to revert to pasture and marsh, thus providing favorable conditions for the spread of malaria. Extensive deforestation by aggravating the flood problem added to the difficulties. It is well known that certain sections of south Italy which, in the eighth century, were sites of large and prosperous communities have since been rendered desolate and barren by the ravages of malaria. The increase in the area affected in the southern part of the Peninsula since 1860 has been extraordinarily rapid. In 1880 only six of the sixty-nine provinces of Italy were entirely free from the disease; in 1885 there were only two; in 1902–5 there were eleven and in 1923, seventeen.

The close connection between malaria and marshes was early recognized; indeed, long before the relation of the disease to the mosquito was known. The name itself (mal-bad; aria-air) owes its origin to the common belief that the foul air from swamps carried the infection. Naturally the first measure of protection undertaken involved the drainage or filling in of overflow lands or, failing in this, the abandonment of the vicinity as a human habitation, at least during the summer season. At this time of the year drought turns many streams into chains of stagnant pools which with the high temperatures then prevailing, provide the optimum conditions for mosquito breeding.

REMEDIAL MEASURES

The reclamation of poorly drained land has always been in Italy one of the two most important lines of attack on the malarial problem. When Italy became a united Kingdom in 1870 there were over four and one half million acres of land with drainage so bad as to be a menace to health. A vigorous cam-

[1] However, the death-rate in recent years from measles, from typhoid or from tuberculosis is larger than that from malaria. The mortality from tuberculosis in 1923 was over sixteen times that from malaria.

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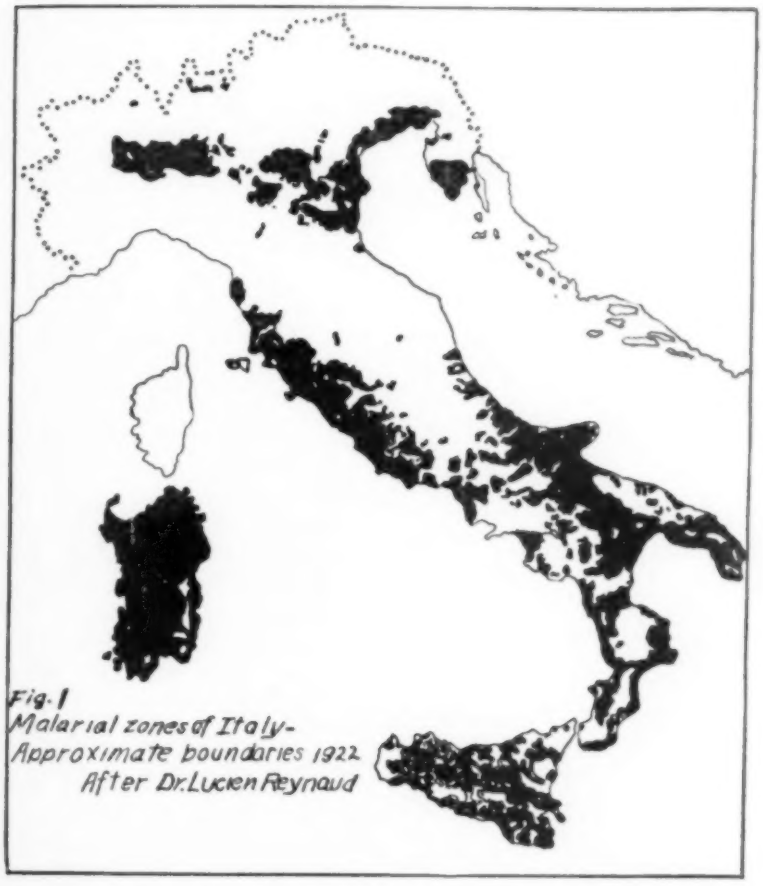

paign of state reclamation begun in 1880 has to date restored to use about one half of this acreage. Of the total which required improvement over three fifths was in north Italy, although the warmer central and southern parts of the Peninsula and the islands have always been the worst infected with malaria. Agricultural development has quickly followed the completion of the government drainage projects in the north; in the central and south it has lagged. The reclamation work has not only reduced the breeding of anopheles, but by improving living standards it has increased the physical well-being and resistance of the people to malarial attack.

A second and no less effective measure in the antimalarial campaign has been to make quinine, the principal specific, available to all. Though the virtues of this drug had been known since the seventeenth century it was not until the government took over its manufacture and distribution as a state monopoly in 1902 that it was placed within the reach of even the poorest peasant. Its distribution free or at small cost has been a tremendous boon to rural Italy, and the enforcement of the "quinine laws" has been marked by sharp declines in the malarial death-rate.

The real modern antimalarial campaign in Italy dates from the beginning of the present century. The discovery

MALARIA AS A FACTOR IN ITALIAN ENVIRONMENT

By Professor W. O. BLANCHARD
UNIVERSITY OF ILLINOIS

ITALY has long been the classic land of malaria. From whence it came or when introduced is not known, but that it was well established in the Peninsula long before the Christian era is certain. For at least twenty-five centuries it has taken a heavy annual toll of life,[1] and the economic loss through decreased efficiency of labor and reduced utilization of areas subject to the disease have been enormous.[2] Even to-day one third of the total area and 40 per cent. of the population of the entire Kingdom are in communes officially "malarial." The number actually living in the infected *parts* of such communes is about 12 per cent. of that of Italy or about four million people. The number of cases "officially reported" annually runs over two hundred thousand and it has directly or indirectly affected the social and economic welfare of the whole population.

In the centuries following its introduction into Italy devastating wars, both civil and foreign, by discouraging agriculture and especially by their destruction of the irrigation and drainage systems, caused much of the cultivated land to revert to pasture and marsh, thus providing favorable conditions for the spread of malaria. Extensive deforestation by aggravating the flood problem added to the difficulties. It is well known that certain sections of south Italy which, in the eighth century, were sites of large and prosperous communities have since been rendered desolate and barren by the ravages of malaria. The increase in the area affected in the southern part of the Peninsula since 1860 has been extraordinarily rapid. In 1880 only six of the sixty-nine provinces of Italy were entirely free from the disease; in 1885 there were only two; in 1902–5 there were eleven and in 1923, seventeen.

The close connection between malaria and marshes was early recognized; indeed, long before the relation of the disease to the mosquito was known. The name itself (mal-bad; aria-air) owes its origin to the common belief that the foul air from swamps carried the infection. Naturally the first measure of protection undertaken involved the drainage or filling in of overflow lands or, failing in this, the abandonment of the vicinity as a human habitation, at least during the summer season. At this time of the year drought turns many streams into chains of stagnant pools which with the high temperatures then prevailing, provide the optimum conditions for mosquito breeding.

REMEDIAL MEASURES

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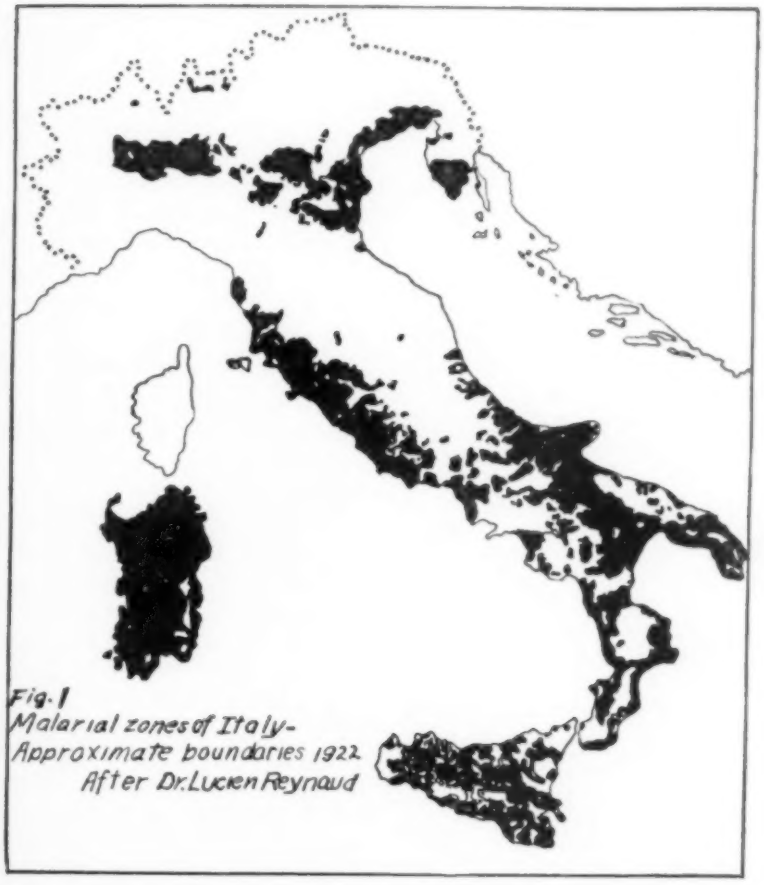

Fig. 1
Malarial zones of Italy-
Approximate boundaries 1922
After Dr. Lucien Reynaud

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of the rôle played by the anopheles mosquito as the transmitter of the malarial parasite gave a tremendous impetus to the fight, and high hopes were entertained for the speedy elimination of the disease. Needless to say, they have failed of realization. True, the discovery placed additional weapons at the disposal of the campaigners. The oiling of stagnant waters, the introduction of mosquito-eating fish, the screening of dwellings, all came to be a part, though a minor part, of the campaign. The major credit for the reduction of the malarial menace still rests upon the drainage and quinine measures.

The Campagna

The work of "bonification" or improvement, by which the malarial districts are being gradually reclaimed may be illustrated by the Roman Campagna, for centuries one of the most notorious of malarial districts.

The Campagna is a vast plain about the capital city, underlain by impervious clays. The soil is fertile, the climate good and the presence of an excellent market in the capital seemed to furnish all the requisite conditions for a prosperous agricultural region. Indeed, in ancient times, this section supported a dense population, but for centuries it has been desolate and all but forsaken.[3] Less than 10 per cent. has been under cultivation. Without forest, towns or permanent homes it has been inhabited in winter by scattered herdsmen, but even these retreated with their charges to the mountains in summer. For the past half century the government has repeatedly tried to colonize the region but until recently with little success. Of late the prospects have been more promising. In addition to general reclamation works and quinine legislation various economic inducements have been included, *e.g.*, the building of roads, introduction of electric power, extension of long-time loans to settlers, exemption of buildings from taxation and the providing of agricultural experts as teachers. From 1900 to 1906 the proportion of the inhabitants affected by malaria was reduced from 32 per cent. to 4 per cent. and the agricultural revival is changing the whole appearance of the Campagna (see Fig. 2).

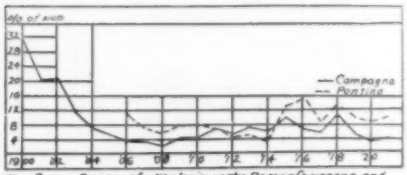


Fig. 2. Cases of Malaria in the Roman Campagna and Pontine Marshes. After Dr. Lucien Reynaud

Distribution

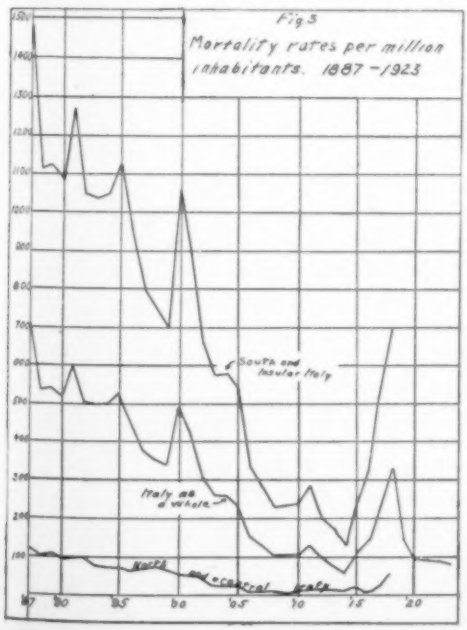
The distribution map of malarial zones (Fig. 1) shows a striking resemblance to the physical map. The dependence of the disease upon the anopheles mosquito as the carrier naturally confines it largely to the plains region, where favorable conditions for the propagation of mosquitoes exist. This is especially unfortunate for Italy, since with a dense population still chiefly agricultural it needs every acre of soil available for food production, doubly so since the area of lowland is so limited. It is estimated that for Italy as a whole only one fifth of the surface is plains, the remainder being equally divided between mountain and hill land. Assuming that the mountain areas are free from malaria, this means that more than one half of the plains and hills, the most productive of Italy's lands, are malarial zones.

In north Italy the Po valley and north Adriatic coast, in central Italy, the lowlying coastal plains, are favorable malarial areas. The mountain streams, checked in their descent from Alps and

[3] Depopulation that set in with the fall of the Empire apparently reached its lowest stage in the seventeenth and eighteenth and first half of the nineteenth centuries. Ashby, T., "The Roman Campagna in Classical Times," London, 1927.

Apennines, deposit their silt, clog up their lower courses and provide extensive overflow lands. Dunes aid in lagoon formation along the coast, and even in the hill and mountain country open quarries and crater lakes have been prolific centers of infection. In south Italy and on the islands the infected area includes considerable upland as well as the valleys and coastal plains. Here the higher temperatures and more marked seasonal irregularity of the river region are more favorable for mosquito breeding. It is in this southern portion of Italy that the disease carries with it a large proportion of fatalities, while in the north it is very mild. Thus, Basilicata in the extreme south had from 1901 to 1905 an average malarial death-rate in proportion to the number of inhabitants, fifty times that of Lombardy in the north. Malaria may well be charged with a considerable share of the responsibility for the retarded development of this southern part of the peninsula and the island.

Figure 3 shows the decline in death-rate. The decrease is most striking.



Thus from 1887 to 1902, the period preceding the quinine legislation, the mortality averaged fifteen thousand annually; from 1903 to 1905, with the enforcement of the malarial laws, the average fell to about one half that figure. Fluctuations are of course to be expected, partly in response to climatic differences, partly as a result of human activities. The latest recrudescence, it will be noted, came during the war period when the exposure of vast numbers of men and their movements from place to place were bound to spread the disease. In addition war activities not only interrupted the antimalarial campaign but actually destroyed vast irrigation and drainage systems, thus releasing the check upon mosquito breeding.

The number of deaths is of course only a part—and but a small part—of the total loss and suffering caused. From 1919 to 1923, inclusive, there were officially reported an average of fifty-six cases of illness for every death. How many malarial attacks were never officially reported is, of course, unknown, but the number must have been large. A disease so common and one in which the standard specific—quinine—may be administered by any one, together with the fact that many of those affected live in isolated sections would indicate that the numbers officially reported are far under the real figures.[4] Professor B. Goss estimates that the average annual death-rate of fifteen thousand from malaria between 1903 and 1905 represented some two million cases, or a ratio of one death to one hundred and thirty-three attacks.

In addition to the marked success of the antimalarial measures in saving life there have been notable economic results. The national government spent in the

[4] Malarial illness began to be officially reported in 1902. After reaching a high point of 323,000 in 1905 they declined and in recent years have usually been less than 250,000.

work from 1900 to 1920 about $100,000,000. The improved land has an estimated value of $400,000,000. It is of course recognized that the accomplishment in stamping out the disease has not been everywhere satisfactory or commensurate with the cost.

The most common effect of malarial infestation has of course been depopulation and the reversion of land to waste or to pastoral use. This change in the type of land utilization has resulted in a modification of agricultural methods, of land ownership, of population distribution and of emigration. For example, since the anopheles works at night and chiefly in summer, the agriculturist must spend that part of the day or season in the hills. This has favored the grouping of the population into towns in the uplands, rather than in scattered rural homes on the cultivated land. Thus in south Italy where malaria is at its worst, though a non-industrial region, the percentage of the inhabitants in towns is greater than in the industrial north. As a consequence of such an arrangement much labor is lost through the workers having to walk long distances to and from their fields. Intensive agriculture, favored by a dense population, is correspondingly handicapped. Latifundia and absentee landlordism have been fostered and a strong impetus given to the emigration of the hungry population to more favored lands. Thus, though primarily a rural or agricultural problem, its effects are directly or indirectly felt throughout the whole social and economic scheme.

THE BIO-ECOLOGY OF FOREST AND RANGE

By WALTER P. TAYLOR and W. G. McGINNIES

THERE are some 470,000,000 acres of forest land and some 1,055,000,000 acres of range and pasture land left in the United States. Attempts to develop agriculture on cut-over coniferous forest lands in the Southwest have usually failed. Likewise, attempts to use the semi-arid range lands for dry-farming have not been successful. Such facts indicate that these areas probably are filling their highest use as producers of timber, forage, and associated wild life. Unless our systems of farming make unprecedented changes they should always remain as forest and range.

Our forests are being depleted at least four times as fast as timber is being grown. In spite of the prevalent use of brick, metal, concrete and other wood substitutes to-day, the demand for wood and wood products is as insistent as ever. Nor is there any likelihood that it will fall off in the future. Regularly recurrent drought years emphasize the inadequacy of the forage resource. The specter of overgrazing threatens livestock production on the western ranges. At the same time the need for meat and meat products is increasing. The value of these commodities certainly makes them deserving of scientific attention.

On critical examination, almost every outstanding problem concerned with the relation of organisms to environment is seen to have a biotic setting. Under natural conditions, a study of vegetation alone or animal life alone lacks completeness. Neither one by itself makes up an independent unit. The basic unit is the biome and its physical environment. Thus we find that forest and range research entails a rather comprehensive study of all forms of organic life together in their inorganic surroundings.

Clements (MS) has said: "All of the biological processes of the community are expressed in (1) response to the habitat, (2) reactions upon it, (3) coactions between the members of it." Researches on response to habitat and of plant reactions on habitat are numerous. Reactions on habitat by animals have received little attention. Some studies of interactions or coactions between plants and animals, animals and plants, animals and animals, and plants and plants, have been made, but it is believed that augmented attention will produce much valuable information.

The significance of bio-ecology to the problems of forest and range lies in the fact that the grazing of domestic stock, wild game and grass and browse-feeding rodents is often a dominant factor in the environment. The degree of grazing may in a large way determine the character and amount of vegetation present. In the forest and range environments, available moisture is often the greatest single factor operating to limit or promote vegetative growth. Close cropping reduces the moisture available for plant growth by increasing losses of water by run-off, percolation and probably evaporation. The effects of this partial desiccation are cumulative and in a few years may entirely change the character of the environment. Furthermore, the influence of grazing conditions on the headwaters may radically change environmental conditions many miles away by causing streams to dry up or floods to sweep through the valleys.

In Arizona and New Mexico, there is one of the largest continuous forests of western yellow pine in the country. In certain localities the burning or reckless cutting of this timber have had serious and far-reaching effects. Physical and

biotic factors of site have been modified to such an extent that recovery will be slow, if, indeed, it takes place at all. Overstocking the yellow pine type with sheep and cattle, as Pearson has shown, has jeopardized the forest of the future. It is suggested as a possibility that woods rodents, such as, for example, the porcupine and certain tree squirrels, and even forest game, having in places less timber to work on, and being relieved somewhat from the pressure of their natural enemies, the predatory animals, have sometimes become forest destroyers of considerable importance.

Many birds are known to play a significant part in extending the distribution of the thickets in which they dwell. Many years ago, Barrows[1] assigned birds an important rôle in forest rotation and in resurfacing with vegetation tracts swept bare by wind, water, fire or the hand of man. It is probable that Forbush[2] is correct in saying that birds alone would shortly replant all cleared lands were it not for the various tools of cultivation. Crows, jays and magpies have a special predilection for gathering and storing seeds. In this process many seeds are planted. Numerous other fruit and seed-eating species of birds and mammals incidentally plant trees and shrubs. The Douglas squirrel of the northwest caches the seed of the Douglas fir in the forest floor and is one of the factors which give the species a prominent place in the region.[3] The red squirrel assists in replanting hardwoods, *e.g.*, oak, beech and hickory.[4] McAtee has pointed out[5] that effective distribution of the seed of the best timber trees, as the pines, hickories, oaks and chestnuts, occurs through transportation by birds and rodents.

Bio-ecology of Watersheds

The forest and range problems are more serious and far-reaching than those that involve merely the production of timber and forage. The existence of agriculture and industry in the semi-arid regions is dependent upon the successful maintenance of watersheds. This entails retention of an adequate cover of forest and lesser vegetation.

As Thornber has stated[6] the reclamation of desert lands is a very difficult matter. "The . . . tendency of all our arid lands is to revert to their natural desert condition. . . ." The history of mankind shows that the fight against the slow forces of nature has been a losing one, and "except in the Valley of the Nile, where irrigation has been carried on under peculiar conditions, we have yet to find a single example of a permanent irrigation agriculture." At the present time, various reservoirs supplying water for the farms on irrigation projects in the Southwest are silting up faster than they should. As a result of over-grazing in the past on the slopes from which the waters are derived, the former cover of perennial grasses is largely gone over vast areas. Every heavy rainstorm tears away some of the soil and carries it toward or into the storage reservoirs.

The silt question is important also in relation to the proposed water and power development of the Colorado River. The total amount of silt brought down every year by this stream was determined by Forbes in 1900 to be in the neighborhood of 61,000,000 tons, or enough to make 53 square miles of

[1] Report for 1890, Chief, Division Ornithology and Mammalogy, U. S. Department of Agriculture, pp. 280–285, 1891.

[2] Department Bulletin No. 9, Massachusetts Department Agriculture, p. 47, 1921.

[3] Hofmann, *Ecology*, 1:53, 1920.

[4] Cram, *Jour. Mammalogy*, 5:40–41, 1924.

[5] Roosevelt Wild Life Bulletin 4:101, 1926.

[6] Technical Bulletin No. 6, University of Arizona Agricultural Experiment Station, Jan. 15, 1926, foreword.

alluvial soil 1 foot deep.[7] Later and more accurate determinations indicate this estimate is probably only about one third of the actual amount.

Experiments have shown that the immediate run-off from non-forested areas after storms is as much as twenty-eight times as great as from forested tracts. In a similar manner, heavy grazing increases run-off through removal of vegetation or a change in its character. Forsling[8] has shown that on a 15 per cent. slope increasing the vegetation from .16 to .37 density decreased run-off 30 per cent. and erosion 60 per cent. The efficacy of different types of vegetation in the prevention of erosion is shown by the work of Miller[9] who found that on a 3.68 per cent. slope the removal by erosion of seven inches of soil will require twenty-nine years on uncultivated land, fifty-six years under continuous cultivation of corn, 150 years under continuous wheat, and 3,547 years under continuous bluegrass sod. Under a good rotation or under continuous grass, the nitrogen losses are greatly reduced.

The association is close between erosion and uncontrollable floods. According to Bennett, failure to build terraces on sloping fields and to plant grass and trees on the steeper lands accounts for much of the excess water that recently swept down the Mississippi. He further states that a wise combination of storage reservoirs, hillside terraces and use of grazing and timber lands for grass and trees will effect practical flood control as nothing else will.

Jones[10] called attention to the fact that while war changes forms of government, misuse of natural resources, and particularly soil and cover, destroys civilizations.

The Tigris and Euphrates Valleys, long before the Christian era, contained prosperous irrigated valleys and grass-covered, forested slopes. The timber on the higher regions was first removed, followed later by the destruction of the grasses on the adjacent slopes. The result is one of the great catastrophes of history, and the one-time grandeur of these nations is now but a memory.

Hewett recently called attention to a similar state of affairs in northern Africa. Written identifiable records, going back at least twelve hundred years, indicate a former time when forest and other vegetation clothed the Atlas Mountains. Removal of this vegetation evidently brought about destructive erosion, more widespread desiccation, and consequent depopulation. Rome tried to stem the tide of the advancing sand, but to no avail. Now modern France is at work on the task of attempted rehabilitation.

Brückner, Zon, Lowdermilk and others have adduced evidence to indicate that removal of forest does actually effect a change in the climate in the direction of aridity. Deforestation, desiccation, depopulation; so goes the sequence.

In many respects our own southwest is like Mesopotamia and Northern Africa. Throughout western Texas, New Mexico, Arizona and neighboring states, the vast herds of the stockmen of the early days have left their mark. Over-grazing has profoundly disturbed natural conditions. Range rodents (*e.g.*, rabbits, prairie dogs, kangaroo rats and ground squirrels), formerly in equilibrium with the vegetation, have assumed a new and destructive rôle. Domestic stock and these native rodents compete for the available grasses. The effects on the vegetation-cover are severe and when enhanced by drought are disastrous.

[7] Breazeale, Technical Bulletin No. 8, University of Arizona Agricultural Experiment Station, Mar. 1, 1926, p. 165.

[8] U. S. Forest Service Grazing Research Program, 1926.

[9] *Journal American Society Agronomy*, 18: 153–160, 1926, taken from *Biological Abstracts*, 1:130, 1926, original not seen.

[10] "Survey of the Erosion Problem," Southwestern District, U. S. Forest Service, Dec., 1923, p. 3.

Clements and other observers have found that the desert plains extending from Odessa, Texas, to Sentinel, Arizona, now supporting scattered zeric shrubs and ephemeral forms only, show relicts of a perennial grassland formation. A vast area, probably formerly protected by these perennial grasses, is now subject to cumulative destructive erosion and increasing desiccation.

Animals and Soil

There is considerable evidence that there exists a soil succession comparable to succession on the surface, each stage marked by the presence of a definite biotic formation. This succession is due in a large part to the action of organic life on the soil itself or on the physical factors influencing it. The importance of vegetation as a soil builder has often been demonstrated. Animals also are important. Not only the microfauna of the soil, but certain larger animals, as insects, worms, amphibians, reptiles, birds and mammals play a part in soil development. Every one is familiar with the earthworm's outstanding reputation as a soil maker. That other animals play an important rôle is doubtless not so widely appreciated. Yet Shaler[11] in his paper on "The Origin and Nature of Soils" says that ants produce a far greater effect on soils than earthworms. Shaler thinks the vertebrates exercise an influence on the soil perhaps as great as that of all their lower kindred. He assigns to mammals the most effective rôle of all in biotic soil influence. The ways in which animals affect soils include burrowing, storing, addition of excreta and deposit of their own dead bodies. The aggregate of soil working in the western United States by pocket gophers, ground squirrels, prairie dogs and kangaroo rats is enormous. Shaler suggests that if all the skeletons of vertebrates that have become a part of the soil since the close of the last glacial period had remained upon the surface they would probably cover the land with a layer of bony matter some feet in depth.

[11] Twelfth Annual Report of Director of U. S. Geological Survey, Part I, Geology, pp. 213–345, 1892.

Bio-ecology as a Safeguard Against Economic Loss

This phase, which includes protection of trees from insects and rodents, livestock and wild game from predatory animals, and forage grasses and browse from range-destroying rodents, has received a great deal of attention. With insects the "protection" phase is by all odds the most important. With rodents it looms large also, though many species play mixed rôles and some are beneficial. The economic status of most mammals is not well known. Further research on this phase is greatly needed.

Insects are responsible for losses amounting to hundreds of millions of dollars annually to agriculture, forage and forest. Estimates of losses to crops in the United States from rodents total no less than $500,000,000 each year. Losses on the open range alone are estimated to aggregate more than $150,000,000 annually.[12] Some idea of the losses to individual states may be gained from the following estimates submitted by directors of agricultural extension, Montana, $15,000,000 to $20,000,000; North Dakota, $6,000,000 to $9,000,000; Kansas, $12,000,000; Colorado, $2,000,000; California, $20,000,000; Wyoming, 15 per cent. of all crops; Nevada, 10 to 15 per cent. of all crops, or $1,000,000; New Mexico, $1,200,000 loss to crops and double this amount to range.[13] Howard has pointed out that the people get only so much of the cultivated crops as the

[12] Bell, Yearbook Separate No. 855, U. S. Department of Agriculture, 1920, pp. 421, 423, 1921.

[13] Bell, Yearbook Separate No. 724, same, 1917, p. 4, 1918.

insects leave over. Similarly on the range, livestock utilizes the forage left by rodents.

Predatory animals cause tremendous losses of domestic animals and valuable wild game, especially deer. A mountain lion in a good deer country will kill one deer or more per week. Losses to the livestock industry from predatory animals have been estimated at $20,000,000 to $30,000,000 annually.[14] On the other hand, the destruction of predatory animals may favor the increase of certain rodents. At the present time, losses from rodents are many times more serious than those from predatory animals. In rare instances, killing of predatory animals may even help to bring about an abnormal increase of big game, so that overpopulation, range and forest destruction and starvation of the game may occur.

Acquisition of further information on the complicated interrelationships involved should help determine the best policies to pursue to insure the greatest good to the greatest number.

Bio-ecological Relations of Game, Forest and Range

The game and fur-bearing species of animals, most of which, including fishes, game birds and game mammals, are to be found on the forested lands or on the open range areas, are legitimate integral parts of their forest and range habitats. Value of wild life is hard to estimate. It is certain, as Adams [15] has said, that the animal crops grown in forests may be made to produce an annual revenue of the utmost value in forestry. The same is probably true of small game, at least, on grazing ranges generally.

Associated with the persistent overgrazing in the southwest has been a steady decline and even extermination of valuable species of game birds; also, often, of fur-bearing and game mammals. The virtual or complete extinction of the masked bobwhite in southern Arizona may be cited as probably due to a combination of over-grazing and drought in its former range. Grinnell[16] asserts that not overshooting, but the removal through grazing by livestock of the cover of vegetation necessary for food and shelter is the principal cause of game scarcity on the national forests of California. The increased amount of silt in streams and their fluctuating volume, due largely to deforestation and overgrazing, have in many cases made streams unfit for fishes. The Kaibab deer and Yellowstone elk problems indicate the need for more information on the effects of big game on summer and winter grazing ranges, especially where this range is used at same season by domestic stock. With the increasing demand for more game and the need for augmented production of livestock, the pressure on the ranges tends to increase in severity.

Forest, Forage and Game as Crops

Forests, forage, wild game and water have always been considered gifts of nature. Even in scientific circles a full appreciation of man's influence on the production of these commodities does not seem to exist. Why should man not grow forage, timber and game on a crop basis? Yet, in America at least, these valuable resources have been utilized as *gifts* rather than developed as *crops*. One of the results is that while production in almost every other branch of agriculture has increased, in forest, forage and wild life it has decreased. The underlying principles governing the maximum production in both cases are largely bio-ecological and upon these

[14] Bell, Yearbook Separate No. 845, same, 1920, p. 289, 1921.

[15] Roosevelt Wild Life Bulletin 3: p. 656, October, 1926.

[16] *Journal of Forestry*, 22: 837–845, 1924.

must be based practices that will yield the best results.

Bio-Ecological Nature of the Problems Involved

The biota on an area at any given time presents the summation or integration of all the factors acting to produce it. Biotic as well as physical conditions are almost universally dynamic. The processes of to-day shape the results of to-morrow. Because of this incessant change in the living network and its physical habitat no satisfactory solution of any phase can be reached without a close correlation with other phases.

It thus appears that convincing results on an adequate scale can only be obtained through bio-ecological methods. The questions presented, almost infinite in their complexity, must be analyzed, so far as practicable, into their component parts for solution, the results obtained to be synthesized later into the required principles for the guidance of the future economic development of the region.

The bio-ecologist probably should be and doubtless will continue to be a specialist in some restricted field in which he will learn more and more about less and less. But if he is to discharge his true functions he must also cultivate a broad view. He should develop the links between the sciences, especially between botany, zoology, soil science, physiography, geology and engineering. He should know more and more about more and more.

It is unnecessary, however, for the zoologist to become a botanist, or the botanist a zoologist, to acquit himself creditably. We have tried to show the need for a comprehensive view of each problem as it arises, and an appreciation of the necessity for considering it both on the plant and animal sides. The plea for bio-ecology is simply one for more adequate workmanship. More thorough instruction in zoo-ecology, and especially bio-ecology, at forest schools and in the universities generally, is desirable. The higher vertebrates, especially birds and mammals in their various relations to environment, should receive more time and attention in the curriculum than they have in the past. So also should the vitally important interactions or coactions between plants and animals, and animals and plants.

A corollary of the bio-ecological theorem is that investigators must work together. The scientist must himself initiative and carry through effective cooperative research enterprises. In no field is this more pertinent than in the field of bio-ecology. Such enterprises, if given the generous support that the needs of the case require and justify, promise much for the future.

THE PROGRESS OF SCIENCE

JOHN HUNTER

1728–1793

WHY do scientists write and rewrite histories and biographies of their great men in spite of the fact that they have been written many times before? The populace might be of the opinion that if a history of a man or of an event is thoroughly investigated and published it ought to stand for all time. But there are two factors we must continually bear in mind in forming a comprehensive judgment of the lifework of any great man.

First, the great men are simply instruments in the course of a historic process, their life-work is never so complete that it could not receive a broader interpretation by posterity—owing to the existence of more refined methods of investigation and more penetrating historic knowledge.

Secondly, the attitude of the human mind is continually changing; being influenced mainly by environment and heredity. The mind of any special generation is not identical with the mind of any other generation as regards its conception and viewpoint of any particular scientific phase. Furthermore, different individuals hold the same event or process in their minds in different perspectives, and the net outcome of the viewpoint of later generations is the result of fusion and compromise between many different views.

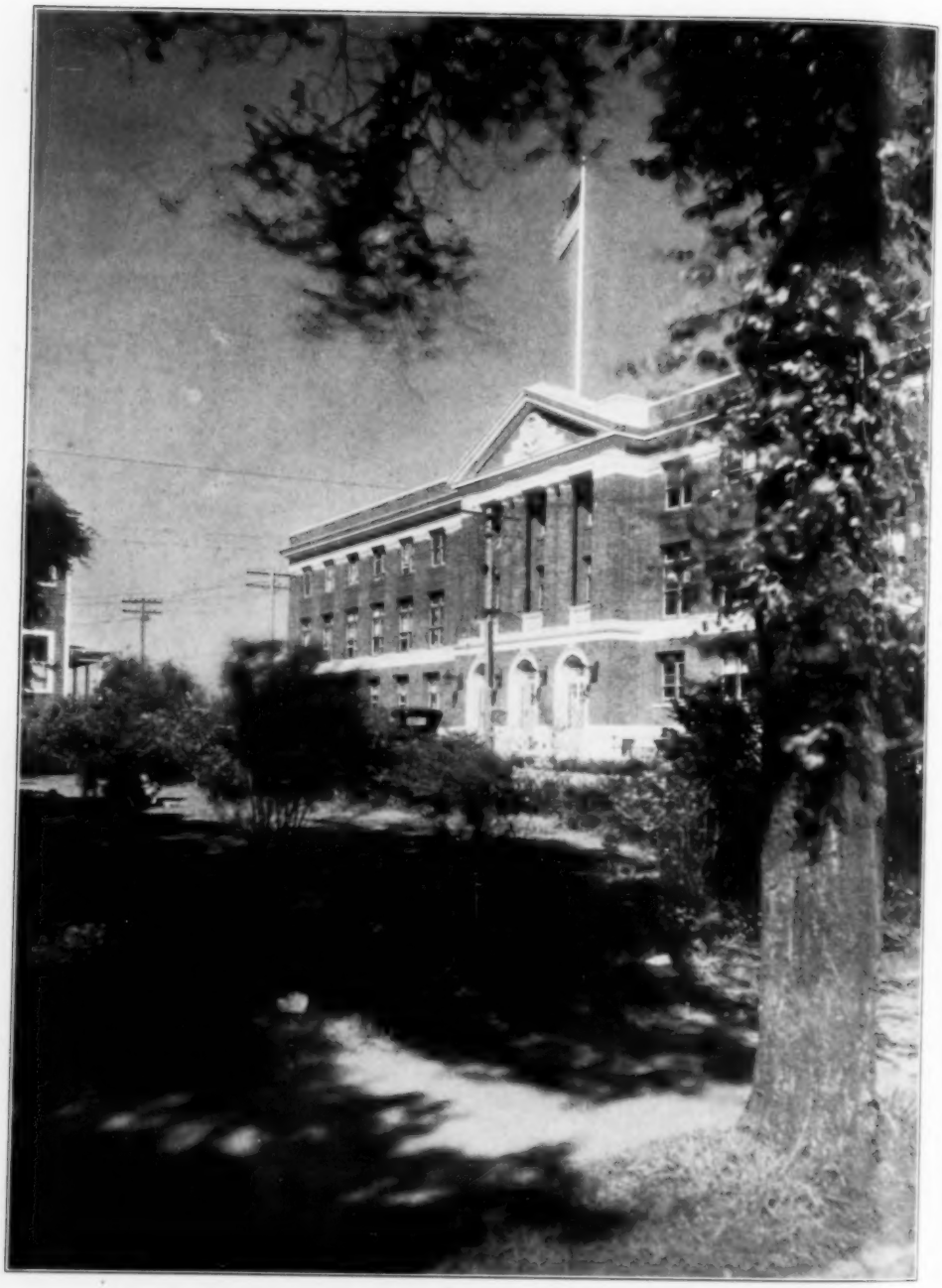
These are the obvious reasons why history and biographies will have to be written and rewritten by every new generation: their environment and necessarily their conceptions are different from ours or those of John Hunter—*Tempora mutantur et nos mutamur in illis.*

John Hunter, the illustrious English surgeon, anatomist, zoologist and physiologist, lived at a time (1728 to 1793) when a great revolution which proved disastrous for science had just passed over. The only representative of that stormy period who achieved scientific progress of enduring value was Sir Isaac Newton. In the period following this, in the eighteenth century, there was marked retrograde movement of science owing to the disorder in national and social affairs which followed the revolution. Great investigators like Hailes and Bradley are simply isolated landmarks in this historic desolation. Fifty to sixty years of complete peace, order and security brought the torch of science back to bright illumination. Toward the end of the eighteenth century and the beginning of the nineteenth century we meet with men like John Hunter, Priestley and Hutten, and at the beginning of the nineteenth century the English nation is blessed by Cavendish, Davey, Wollaston, Brewster, Herschel, Robert Brown, Dalton, Faraday, Murchison. John Hunter, the anatomist and surgeon, was born in Kilbridge, Scotland, but lived for the longest time in England itself. His parents belonged to the Protestant faith and possessed a small estate in Scotland. In the limited space permitted by the editor it is not possible to trace any effect of inheritance or enter upon a study of his personality. Those interested in these questions are referred to chapter 5, p. 121, of Hemmeter's "Master Minds in Medicine." The chapter is entitled "The Rôle and Function of Great Men in Medical History." Within the compass of this sketch the best plan to pursue is to describe in an abstracting manner his most telling contributions to medicine and science, and to leave it to the reader to form a conception of the colossal ingenuity, penetration and conservative critical judgment of this surgeon and anatomist.

JOHN HUNTER
1728–1793

Toward the end of the eighteenth century he announced a theory of the origin of gastric ulcer and perforation, attributing them to erosions by the acid gastric juice. Although based upon the authority of Spallanzani it lost ground later on. At the present day there can be no doubt that the view of specialists concedes at least a partial correctness to the view of Hunter. In 1721 J. Hunter demonstrated that in scrotal hernia the protusion of the peritoneum preceded the descent of the gonad, and argued that the peritoneum must be pushed ahead of the intestinal loops in congenital scrotal hernia, confirming the great Haller in this view. Hunter was one of the first to state that the gastric juice had an acid reaction. Dentistry should be grateful to him because he made a condition *sine qua non* that the pulp must be completely removed if teeth are to be filled successfully. He also made experiments, and with success, to straighten and regulate teeth that were in an abnormal position. His work for dental science alone ought to attract the investigation of scientific dentists (1771). In 1773 he published an investigation concerning the electrical organ of Torpedo. In 1780 he had written several contributions to surgery which broadened the science in every direction. He had extensively practiced vivisection and experiments on animals. He ascribed the processes of inflammation to a reorganizing and reconstructive influence of the body. He was the first to describe phlebitis (inflammation of the veins). In 1785 he made one of the most epoch-making discoveries to surgery, namely, that of collateral circulation. When an artery is ligated or obstructed, the blood is forced with greater pressure and greater quantity into the side branches of the closed artery, and it eventually reaches by collateral passages the same parts which would properly have been supplied by the obstructed vessel. Upon this he founded his treatment of aneurysm by proximal ligature some distance from the aneurysm. Up to the period of antiseptic surgery this remained the prevailing and most favorite method. After that excision of the aneurysm and extirpation came into vogue. In 1786 John Hunter published his epoch-making work entitled "A Treatise on Venereal Diseases." The identity of the "*ulcus molle*" and the primary lesion were doubted by Record, but surprisingly enough the most recent investigations dependent upon the detection of spirochaetes again confirm Hunter. In 1790 he published in conjunction with the doctrine of James Moore his work entitled "On the Nature of Blood Inflammation and Gun-shot Wounds"—the scientific fundamentals for the understanding of the healing process in severed parts. In this publication he advocated the bloodless way of uniting such parts by means of bandages of strips of plaster wherever possible, and preferred this to suturing with stitches. In my work on "Master Minds in Medicine," in the chapter entitled "Leonardo da Vinci as a Scientist" I quote John Hunter's opinion of da Vinci, in order to demonstrate the astonishing erudition and breadth of knowledge in the history of medicine of this eminent English scientist. In speaking of Leonardo, Hunter expresses himself as follows: "I consider Leonardo da Vinci as the best anatomist and physiologist of his time. His teacher and he (the teacher that Hunter refers to here was Marco Antonio della Torre) were the first to know how to arouse the spirit of a study of anatomy." Hunter became a member of the Paris Academy of Sciences in 1782 at a time when only twelve other Englishmen were members of it. He possessed all the qualifications for the making of a great man that Alphonse de Candolle (1911) lists in his "History of the Sciences and Scientists since the Last Two Hundred Years."

JOHN C. HEMMETER



THE MARINE BIOLOGICAL LABORATORY

THE MARINE BIOLOGICAL LABORATORY

THE Marine Biological Laboratory traces its origin from the establishment of the "Anderson School of Natural History" on the island of Penikese by Louis Agassiz in 1873; Agassiz died in the winter of that year, and the school was continued the following summer under the direction of his son, Alexander Agassiz, but was then abandoned. From 1880 to 1886 a seaside laboratory was maintained at Annisquam, Massachusetts, under the direction of Alpheus Hyatt, a student of Agassiz, by the Woman's Education Association of Boston in cooperation with the Boston Society of Natural History. The present organization was established and incorporated in 1888 as the result of an effort made by the group interested in the Annisquam Laboratory to secure an independent and broader foundation. A site was selected at Woods Hole and a plain wooden building, now the south wing of our large wooden laboratory, was erected here and opened for work on July 17, 1888.

The Marine Biological Laboratory was given its name and location on the seashore, because at the time of its foundation the value of the life of the ocean as material for the study of biological problems was beginning to be fully recognized after some fifteen years of fruitful activity on the part of the Naples Zoological Station. The expectations of the advantages to be derived from the study of marine material have, I venture to say, been exceeded in the results. The life of the ocean has proved our greatest asset in the contributions to the advancement of biological science made here. But this asset places no limitations on the use of the other biological materials, and in addition we draw on whatever sources of supply that inland institutions use.

The Marine Biological Laboratory is a *research* institution; all its personnel and facilities are provided to aid in the tasks of the investigators. There are officers to conduct the business of the institution, men to man the boats and nets and other apparatus with which the produce of the sea is collected; others to design and keep in order the elaborate apparatus and equipment and to assign

their use; yet others to ensure a continuous supply of sea-water to rooms and aquaria, to keep our complicated electrical system in order and attend to other mechanical needs; a department to house and feed the workers; a department to care for buildings and grounds; a library personnel and a library that we aim to make the best possible source of reference in its field. All these persons and facilities are at the service of the investigator.

Believing that it is no less our function to produce investigators than to promote the actual work of investigation, the laboratory also offers instruction to a limited group carefully selected from the best students of biology of American universities. These are the young people whose presence enlivens our proceedings for six weeks in the summer. There are also the candidates for professional status in biology, about seventy in number, graduate students beginning investigation or in early stages of a career of investigation, coming from the principal centers of biological investigation in our universities. These fortunate students receive the benefits of the standards and ideals of research of many institutions during the weeks or months of their work at Woods Hole, an advantage to be procured in no other way.

The laboratory is a *cooperative* organization. Its ownership rests in a corporation of some 350 members, the great majority of whom are professional biologists. Its affairs are administered by a board of trustees of thirty-five members elected by the corporation, composed, with but *two most valuable exceptions*, of university professors in various fields of biology of some twenty-five institutions; detailed administration is in the hands of an executive committee of five chosen by the board from its own membership. As substantially all the members of the Marine Biological Laboratory are representatives in one capacity or another of American universities, colleges and research organizations, so in practice the laboratory belongs to these institutions; here they have extra-territorial privileges and abiding place; and the contributions that they make to the support of the laboratory in return for the various uses of their biological departments constitute their recognition of this relationship. In 1924 seventy-two American institutions of learning thus contributed. This relationship is usually maintained through the university departments concerned and is continued at the pleasure of such departments; but in the case of the larger institutions it is a constant and continuing one. The smaller institutions enjoy here the same advantages as larger ones, and thus the handicaps of their necessarily less adequate provisions for research at home are to some extent equalized.

The laboratory is *national* in its scope. There is no sectionalism in its organization or in its life. It was established in New England by New Englanders and is strongly supported by the institutions of this part of the country; but it is no less strongly supported by the institutions of other eastern states; and indeed in proportion to cultural and geographical conditions by more remote states of the Union. Twenty-seven of the seventy-two cooperating institutions of 1924 lie west of the Alleghenies. Twenty-eight states of the Union were represented by the workers, and the following countries—Brazil, Canada, China, England, Holland, Hungary, Japan, Poland, Sweden. The laboratory has indeed numerous other international connections and extends its welcome to all qualified investigators of whatever nation.

The laboratory also represents all fields of biology; it is not controlled by any one biological sect, neither by Dar-

LOUIS JEAN RUDOLPHE AGASSIZ
1807–1873

NATURALIST AND FOUNDER OF THE ANDERSON SCHOOL OF NATURAL HISTORY. THE MARINE BIOLOGICAL LABORATORY IS A DIRECT DESCENDANT OF THIS PENIKESE SCHOOL.

winians or Lamarckians, by vitalists or mechanists, by zoologists or botanists, by morphologists or physiologists. It aims to provide suitable facilities for all kinds of biological work. It thus has no program of its own for the development of one or even several directions of biological investigation, save in the broadest sense. As it is catholic in its membership, so also is it catholic in its interests. This policy keeps it abreast of scientific interests; it ensures the use of means and equipment for the most promising problems of the time; it provides for a constant renewal of strength.

As part of this policy the laboratory avoids salaried appointments on its scientific staff, excepting those concerned in the courses of instruction, who receive small emoluments. The laboratory thus does not enter into competition with universities for personnel. Voluntary leadership in the various departments of biology within the institution has proved most devoted, sufficiently continuous for all matters of scientific policy and also flexible enough to avoid unprofitable specialization of the uses and of the means of the laboratory.

F. R. L.

THE HALL OF FAME

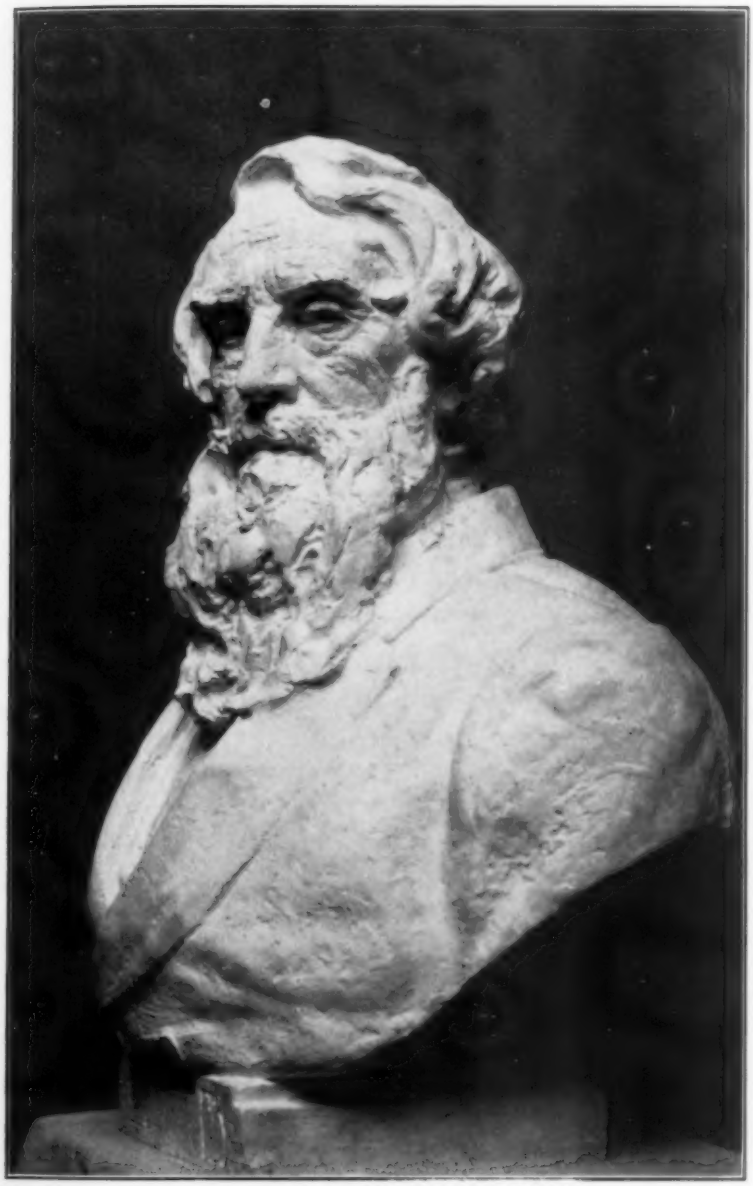
The Hall of Fame, for the immortalization of great Americans and the goal of every distinctive Yankee, is paying due homage to science. When in March, 1900, a gift of $100,000, later increased to $250,000, was made to New York University, it was established that the money should be used in building a colonnade, five hundred feet long, on University Heights, looking towards the Palisades and the Hudson and Harlem River Valleys. The substructure was to be used forever as "The Hall of Fame for Great Americans."

To this end one hundred and fifty panels were planned, to be of a size two by eight feet and to bear inscribed memorial tablets of bronze and to act as pedestals for the bronze busts. Fifty inscriptions were to be made in 1900, provided fifty names should be approved by the judges and at the close of every five years to follow another five names were to go down in bronze. The Senate of New York University, whose vote was final on whether a person should or should not be elected, were confronted with more than one thousand nominations by the hundred electors, well-known citizens throughout the country. At that time only twenty-nine received a majority of votes.

The rules were not closely followed, as can be seen in this report. In 1905 five names were added, in 1910, eight, in 1915, eight, and in 1920, six, making in all, up to 1921, a total of fifty-six names inscribed. Meanwhile seven names of women had been chosen. Had the full quota been reached in the five elections already held, seventy would have been elected, and therefore, allowing for the seven women, the quota for 1925 was twelve names. However, only two were chosen at that election. Thus the total number of tablets is now sixty-five.

Of course the Hall of Fame has a constitution, one which can be amended as readily as our national one, and it has undergone some drastic changes. Whereas, in the original Magna Charta, no foreign-born citizen was eligible to election, this unfair discrimination has been wiped out. In 1922, also, the margin of time after death at which a person becomes eligible was extended from ten to twenty-five years.

Every state in the union is represented in the electorate of the Hall of Fame to-day. The number is the same as that with which it started—one hundred persons, elected by the Senate of the university in the year preceding each quinquennial year, in fairly even numbers from various groups of citi-



SAMUEL FINLEY BREESE MORSE
1791–1872

ARTIST AND INVENTOR. IN 1832 MORSE REMARKED, "IF THE PRESENCE OF ELECTRICITY CAN BE MADE VISIBLE IN ANY PART OF THE CIRCUIT, I SEE NO REASON WHY INTELLIGENCE MAY NOT BE TRANSMITTED BY ELECTRICITY." IN 1836 HE HAD COMPLETED THE CONSTRUCTION OF A PRACTICAL ELECTROMAGNETIC TELEGRAPH SYSTEM.

zenry, including authors, editors and artists, presidents of universities and colleges, jurists, high public officials and women of affairs. As an added precaution of fairness, no person connected with New York University is eligible as an elector.

"The public be served" might well be the motto of the institution. It is their vote which finally places the deserving ones in the position of greatest honor. Robert Underwood Johnson, director of the Hall of Fame, receives names from February 1 to March 15 of the year of quinquennial election, from all who are interested. These are in turn placed before the Senate. Before Dr. Johnson's election in 1919, Dr. Henry Mitchell McCracken, who originated the idea of the Hall of Fame, was director.

We have said that due homage is being paid to science. It is gratifying to the scientific world to know that ten scientists have been elected. The immortalized include Peter Cooper, John James Audubon, Asa Gray, Louis Agassiz, Joseph Henry, Maria Mitchell, Robert Fulton, Samuel F. B. Morse, Eli Whitney and Elias Howe.

At the most recent unveiling exercises, held on May 10, busts of the two scientists, Louis Agassiz and Samuel F. B. Morse, were dedicated. Agassiz's bust, the work of Anna Vaughn Hyatt, was the gift of the American Association for the Advancement of Science and of an admirer of the scientist. George Agassiz, a grandson of the famous man, unveiled the statue.

A granddaughter of Samuel Finley Breese Morse, Miss Leila Livingston Morse, unveiled the bust of the inventor. It was modeled by Chester Beach. Richard E. Enright, former commissioner of police of the city of New York and chairman of the Morse Hall of Fame Memorial Committee, made the presentation. E. N.

WILLARD STRAIGHT HALL AT CORNELL UNIVERSITY

THE HEADQUARTERS OF THE FOURTH INTERNATIONAL CONGRESS OF ENTOMOLOGY WILL BE MAINTAINED IN THIS BUILDING. THE CONGRESS WILL CONVENE FROM AUGUST 12 TO 18.